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SITE-SPECIFIC TECHNICAL REPORT FOR FREE PRODUCT RECOVERY TESTING AT SITE SS-15, SHAW AFB, SOUTH CAROLINA

DRAFT

PREPARED FOR:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
TECHNOLOGY TRANSFER DIVISION
(AFCEE/ERT)
8001 ARNOLD DRIVE
BROOKS AFB, TEXAS 78235-5357

AND

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SITE-SPECIFIC TECHNICAL REPORT (A003)

for

FREE PRODUCT RECOVERY TESTING AT SITE SS-15, SHAW AFB, SOUTH CAROLINA

by

A. Leeson, L. Tatar, M. Place, and S. Walton

for

Mr. Patrick Haas
U.S. Air Force Center for Environmental Excellence
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(AFCEE/ERT)
Brooks AFB, Texas 78235-5357

21 April 1997

Battelle
505 King Avenue
Columbus, Ohio 43201-2693

Contract No. F41624-94-C-8012

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EXECUTIVE SUMMARY

This report summarizes the field activities conducted at Shaw Air Force Base (AFB) for a short-term field pilot test to compare vacuum-enhanced free-product recovery (bioslurping) to traditional free-product recovery techniques used to remove light, nonaqueous-phase liquid (LNAPL) from subsurface soils and aquifers. The field testing at Shaw AFB is part of the Bioslurper Initiative, which is funded and managed by the U.S. Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division. The AFCEE Bioslurper initiative is a multisite program designed to evaluate the efficacy of the bioslurping technology for (1) recovery of LNAPL from groundwater and the capillary fringe, and (2) enhancing natural in situ degradation of petroleum contaminants in the vadose zone via bioventing.

The main objective of the Bioslurper Initiative is to develop procedures for evaluating the potential for recovering free-phase LNAPL present at petroleum-contaminated sites. The overall study is designed to evaluate bioslurping and identify site parameters that are reliable predictors of bioslurping performance. To measure LNAPL recovery in a wide variety of in situ conditions, tests are being performed at many sites. The test at Shaw is one of more than 40 similar field tests to be conducted at various locations throughout the United States and its possessions.

The intent of field testing is to collect data to support determination of the predictability of LNAPL recovery and to evaluate the applicability, cost, and performance of the bioslurping technology for removal of free product and remediation of the contaminated area. The on-site testing is structured to allow direct comparison of the LNAPL recovery achieved by bioslurping with the performance of more conventional LNAPL recovery technologies. The test method included an initial site characterization followed by LNAPL recovery testing. The three LNAPL recovery technologies tested at Shaw AFB were skimmer pumping, bioslurping, and drawdown pumping.

Bioslurper pilot test activities were conducted at monitoring well MW 644. Site characterization activities were conducted to evaluate site variables that could affect LNAPL recovery efficiency and to determine the bioventing potential of the site. Testing included baildown testing to evaluate the mobility of LNAPL, soil sampling to determine physical/chemical site characteristics, soil gas permeability testing to determine the radius of influence, and in situ respiration testing to evaluate site microbial activity.

Following the site characterization activities, the pump tests were conducted. At monitoring well MW 644, pilot tests for skimmer pumping, bioslurping, and drawdown pumping were conducted. The LNAPL recovery testing was conducted in the following sequence at monitoring well MW 644: 48 hr in the skimmer configuration, 101.5 hr in the bioslurper configuration, an additional 23 hr in the skimmer configuration, and 28 hr in the drawdown configuration.

Measurements of extracted soil gas composition, LNAPL thickness, and groundwater level were taken throughout the testing. The volume of LNAPL recovered and groundwater extracted were quantified over time.

Baildown recovery tests were conducted at monitoring wells MW 634 and MW 644. Baildown recovery tests provide a qualitative indication of the presence of mobile, free-phase LNAPL and recovery potential. Overall, the baildown recovery tests indicated a relatively high rate of LNAPL recovery into the wells. At monitoring well MW 644, LNAPL recovered to within 70% of initial levels by the end of the 4 hr baildown test. At monitoring well MW 634, LNAPL recovered to a level approximately 50% of the initial LNAPL thickness. Based on these results, pilot testing was initiated on monitoring well MW 644.

Direct pumping tests were conducted at monitoring well MW 644. Skimmer pump testing was conducted at monitoring well MW 644 in a continuous extraction mode for two days. A significant quantity of LNAPL was recovered during this pump test. The initial LNAPL recovery rate was 23.5 gallons/day, which dropped to 14.5 gallons/day by the second day of testing. A total of approximately 390 gallons of groundwater was produced with an average production rate of 200 gallons/day. LNAPL recovery was significantly greater during the bioslurper pump test than that observed during the skimmer pump test. Bioslurper testing was conducted for approximately four days, resulting in relatively high recovery on the first day (46 gallons/day), with a significant reduction in recovery by day 2 to 28 gallons/day. However, by day 3, LNAPL recovery rates increased to 37 gallons/day, and remained relatively constant for the remainder of the testing. This increase on day 3 corresponds to increasing the pump vacuum and a corresponding increase in vapor flowrate and well vacuum. A total of 150 gallons of LNAPL and 1,240 gallons of groundwater was extracted, with daily average recovery rates of 38 gallons/day for LNAPL and 320 gallons/day for groundwater.

LNAPL recovery rates during the second skimmer pump test were similar to the initial skimmer pump test during approximately 23 hours of continuous pumping. Approximately 21 gallons of LNAPL and 180 gallons of groundwater were recovered during the second skimmer pump test, with daily average recovery rates of 22 and 190 gallons/day, respectively. These results demonstrate that operation of the bioslurper system in the skimmer mode was an effective means of free-product recovery, although recovery rates are significantly lower than during bioslurping.

Drawdown pump testing was conducted to determine if a cone of groundwater depression would enhance LNAPL recovery. The water table was depressed 22 inches below the static water table in monitoring well MW 644. Significant quantities of LNAPL were recovered, with average rates of 30 gallons/day and a total recovery of approximately 54 gallons. Groundwater production rates were on the order of 240 gallons/day, with a total of approximately 440 gallons produced. These results demonstrate that the vacuum gradient maintained during the bioslurper test resulted in higher fluid recovery rates than the 22 inch-groundwater drawdown test.

Bioslurping also promotes mass removal in the form of in situ biodegradation via bioventing and soil gas extraction. Vapor phase mass removal is the result of soil gas extraction as well as volatilization that occurs during the movement of LNAPL free product through the extraction network. Given a flowrate of 12.5 scfm and using an average concentration of 12,500 ppmv TPH and 1,300 ppmv benzene, approximately 65 lb/day of TPH and 4.7 lb/day of benzene were emitted to the air. Thus, mass removal in the vapor phase is significant. Higher vapor mass removal rates are more often sustained at those sites where liquid product recovery is sustained.

The initial soil gas profiles at the site displayed oxygen-deficient, carbon dioxide-rich, high total volatile hydrocarbon vapor conditions at depths from 30 to 40 ft bgl. These conditions indicate that natural biodegradation of residual petroleum hydrocarbons has occurred, but is limited by oxygen availability. Soil gas concentrations were measured during the bioslurper test at monitoring points adjacent to monitoring well MW 644 to determine if the vadose zone was being oxygenated via the bioslurper action. Unfortunately, results were inconclusive based on oxygen measurements, although soil gas permeability testing indicated that a radius of influence of approximately 40 ft could be achieved. In general, it is our experience that oxygenation will occur at monitoring points where a perceptible pressure change is measured. In situ biodegradation rates 0.025 of 21 to mg/kg-day were measured at four different locations. Based on the radius of influence of 40 ft and a hydrocarbon-impacted soil thickness of 40 ft, mass removal rates via biodegradation are on the order of 0.43 to 370 lbs of hydrocarbon per day. Thus, mass removal rates via biodegradation could be more significant than the vapor phase removal rates measured during the bioslurper test. These results indicate that bioventing is feasible at this site. Air injection bioventing is preferable over bioslurping and soil vapor extraction with respect to the elimination of hydrocarbon vapor emissions.

In summary, the on-site testing at Site SS-15, Shaw AFB, included the direct testing of gravity-driven and vacuum-driven LNAPL free product recovery techniques, bioventing, physical sampling, and tests relevant to soil vapor extraction. Liquid phase recovery was sustainable during all pump tests, with the highest recoveries during bioslurping. The in situ respiration test and vadose zone radius of influence testing demonstrate that bioventing may be feasible at this site. Bioslurping appears to be a suitable recovery technique for this site.

DRAFT SITE-SPECIFIC TECHNICAL REPORT (A003)
for
FREE PRODUCT RECOVERY TESTING AT SITE SS-15,
SHAW AFB, SOUTH CAROLINA

21 April 1997

1.0 INTRODUCTION

This report describes activities performed and data collected during field tests at Shaw Air Force Base (AFB), South Carolina to compare vacuum-enhanced free-product recovery (bioslurping) to traditional free-product recovery technologies for removal of light, nonaqueous-phase liquid (LNAPL) from subsurface soils and aquifers. The field testing at Shaw AFB is part of the Bioslurper Initiative, which is funded and managed by the U.S. Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division. The AFCEE Bioslurper Initiative is a multisite program designed to evaluate the efficacy of the bioslurping technology for (1) recovery of LNAPL from groundwater and the capillary fringe and (2) enhancing natural in situ degradation of petroleum contaminants in the vadose zone via bioventing.

1.1 Objectives

The main objective of the Bioslurper Initiative is to develop procedures for evaluating the potential for recovering free-phase LNAPL present at petroleum-contaminated sites. The overall study is designed to evaluate bioslurping and identify site parameters that are reliable predictors of bioslurping performance. To measure LNAPL recovery in a wide variety of in situ conditions, tests are being performed at many sites. The test at Shaw AFB is one of more than 40 similar field tests to be conducted at various locations throughout the United States and its possessions. Aspects of the testing program that apply to all sites are described in the Test Plan and Technical Protocol for Bioslurping (Battelle, 1995). Test provisions specific to activities at Shaw AFB are described in the Site-Specific Test Plan provided in Appendix A.

The intent of field testing is to collect data to support determination of the predictability of LNAPL recovery and to evaluate the applicability, cost, and performance of the bioslurping technology for removal of free product and remediation of the contaminated area. The on-site testing is structured to allow direct comparison of the LNAPL recovery achieved by bioslurping with the performance of more conventional LNAPL recovery technologies. The test method included an initial site characterization followed by LNAPL recovery testing. The three LNAPL recovery technologies tested at Shaw AFB were skimmer pumping, bioslurping, and drawdown pumping. The specific test objectives, methods, and results for the Shaw AFB test program are discussed in the following sections.

1.2 Testing Approach

Bioslurper pilot test activities were conducted at monitoring well MW 644. Site characterization activities were conducted to evaluate site variables that could affect LNAPL recovery efficiency and to determine the bioventing potential of the site. Testing included baildown testing to evaluate the mobility of LNAPL, soil sampling to determine physical/chemical site characteristics, soil gas permeability testing to determine the radius of influence, and in situ respiration testing to evaluate site microbial activity.

Following the site characterization activities, the pump tests were conducted. At monitoring well MW 644, pilot tests for skimmer pumping, bioslurping, and drawdown pumping were conducted. The LNAPL recovery testing was conducted in the following sequence at monitoring well MW 644: 48 hr in the skimmer configuration, 101.5 hr in the bioslurper configuration, an additional 23 hr in the skimmer configuration, and 28 hr in the drawdown configuration.

Measurements of extracted soil gas composition, LNAPL thickness, and groundwater level were taken throughout the testing. The volume of LNAPL recovered and groundwater extracted were quantified over time.

2.0 SITE DESCRIPTION

Shaw AFB is located in central South Carolina. The site under investigation at Shaw AFB is Operable Unit 1 (OU-1), IRP Site SS-15. The organic liquid contaminant is JP-4 jet fuel, and the primary source of contamination appears to be the underground storage tank farms. Figure 1 shows the OU-1 site, including monitoring well locations and the extent of the free-product plume. The area

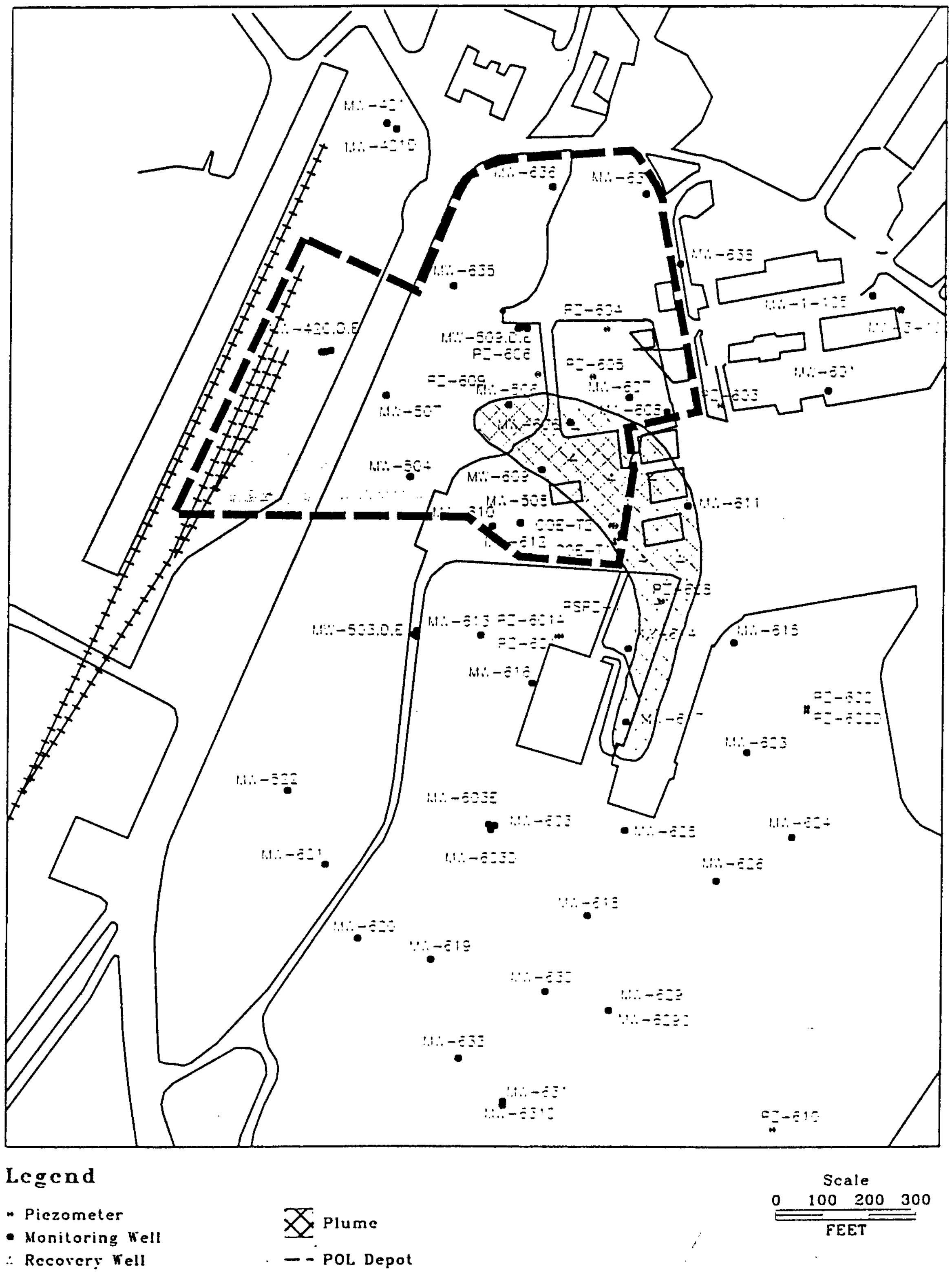

Figure 1. Site Map Showing the Location of Monitoring Wells

under consideration for bioslurping activities is the smaller circular plume located to the south of the two adjoining larger plumes. From these data, the wells that are most likely to yield significant amounts of free product have been identified. Wells MW-634 and MW-644 had fuel thicknesses of 6.85 ft and 6.71 ft, respectively, when measured on January 14, 1996. Measurements taken February 23, 1996, revealed decreased thicknesses of 1.31 ft and 5.64 ft at respective wells MW-634 and MW-644. Depth to product at the two wells ranged from 41 to 44 ft bgs and depth to water from 46 to 49 ft bgs during the January/February 1996 readings.

Preliminary soil analytical results from wells in the area under investigation revealed BTEX concentrations ranging from 29 to 158 mg/kg and TPH concentrations ranging from 27 to 3,700 mg/kg. Groundwater analysis data is limited to samples taken from the POL Yard area, where the BTEX concentration in groundwater was found to be approximately 5 ppm and the benzene concentration approximately 1.4 ppm.

Polycyclic aromatic hydrocarbons (PAHs) have also been found to be present at the POL Yard site. Previous analyses of the groundwater have revealed the presence of four PAHs — acenaphthene, naphthalene, methylnaphthalene, and fluorene. However, all previous analyses of the site soils and groundwater have indicated that the main source of contamination at the POL Yard site is the free-product plume of JP-4 jet fuel.

3.0 BIOSLURPER SHORT-TERM PILOT TEST METHODS

This section documents the initial conditions at the test site and describes the test equipment and methods used for the short-term pilot test at Shaw AFB.

3.1 Initial LNAPL/Groundwater Measurements and Baildown Testing

Monitoring wells MW 644 and MW 643 were evaluated for use in the bioslurper pilot testing. Initial depths to LNAPL and to groundwater were measured using an oil/water interface probe (ORS Model #1068013). LNAPL was removed from the well with a Teflon® bailer until the LNAPL thickness could no longer be reduced. The rate of increase in the thickness of the floating LNAPL layer was monitored using the oil/water interface probe for approximately 5 hr at monitoring well MW 634 and for approximately 4 hr at monitoring well MW 644.

3.2 Well Construction Details

Short-term bioslurper pump tests were conducted at existing monitoring well MW 644. Monitoring well MW 644 is constructed of 4-inch-diameter, schedule 80 polyvinyl chloride (PVC). Total well depth is 49 ft with a screen length of 10.0 ft. A schematic diagram illustrating general well construction details for monitoring well MW 644 is provided in Figure 2.

3.3 Soil Gas Monitoring Point Installation

Three monitoring points were installed and labeled MPA, MPB, MPC, and MPD. The locations and constructions details of the monitoring points are illustrated in Figure 2.

The monitoring points consisted of ¼-inch tubing, with 1-inch-diameter, 6-inch-long screened areas. The screened lengths were positioned at depths of 30, 35, and 40 ft bgl at monitoring point MPA, MPB, and MPC, and at a depth of 16 ft bgl at monitoring point MPD. The annular space corresponding to the screened length was filled with silica sand. The interval from the top of the screened length to the bottom of the next screened length, as well as the interval from the ground surface to the top of the first screened length, was filled with bentonite clay chips. After placement, the bentonite clay was hydrated with water to expand the chips and provide a seal.

Type K thermocouples were installed with monitoring point MPC at depths of 30 and 40 ft bgl.

After installation of the monitoring points, initial soil gas measurements were taken with a GasTech portable O2/CO2 meter and a GasTech TraceTechtor portable hydrocarbon meter. Oxygen limitation was observed at all monitoring points, with oxygen concentrations below 5% at all depths. TPH concentrations were greater than 20,000 ppmv at all monitoring point screened intervals (Table 1). Monitoring point MPD was installed later in the testing; therefore, no initial data is shown.

3.4 Soil Sampling and Analysis

Two soil samples were collected during the installation of monitoring point MPB and were labeled SHW-S-1 and SHW-S-2. Sample SHW-S-1 was collected from 38 to 40 ft bgl and sample SHW-S-2 was collected from 40 to 42 ft bgl using a split spoon sampler with brass sleeves. The samples were placed in an insulated cooler, chain-of-custody records and shipping papers were

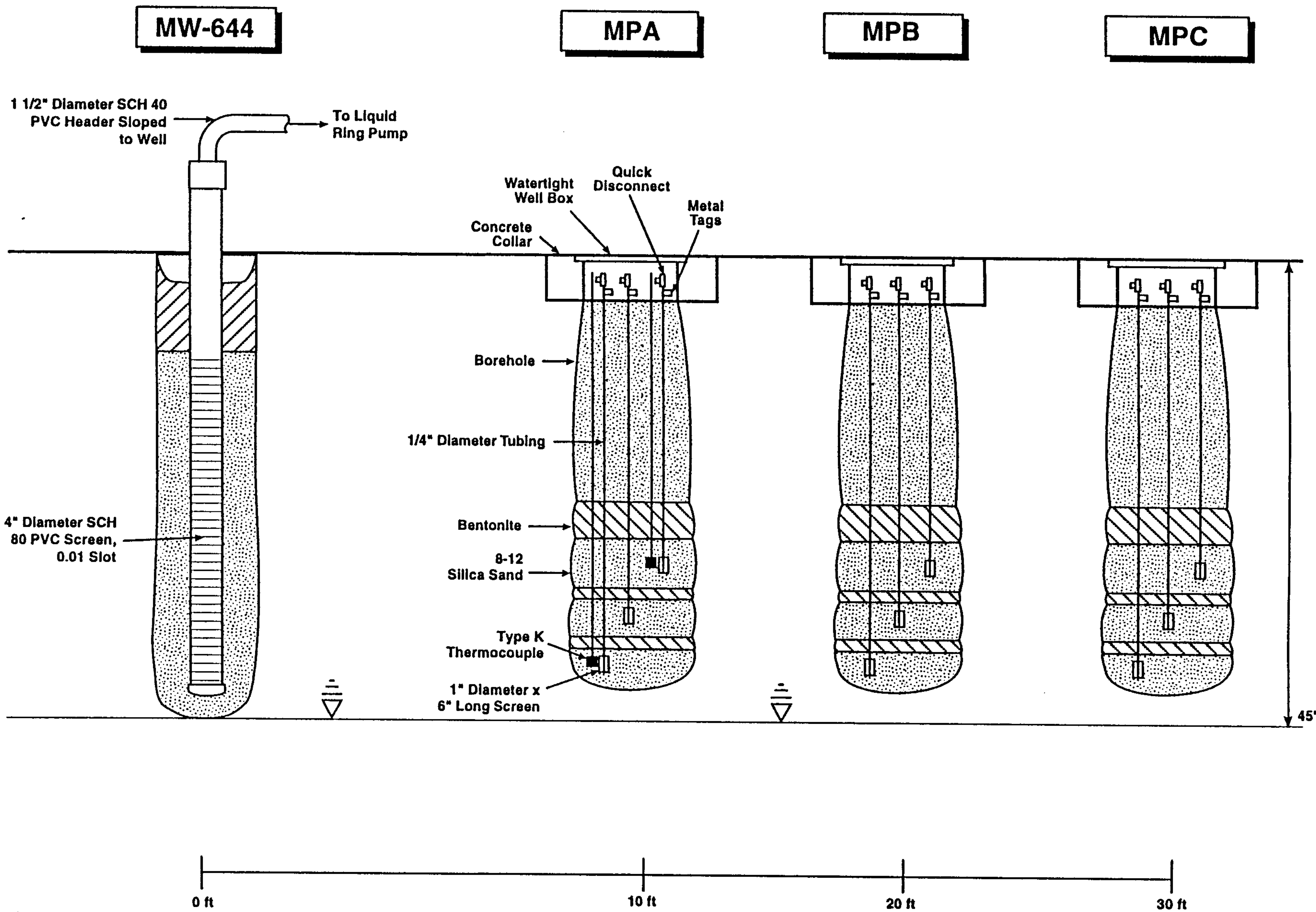

Figure 2. Schematic Diagram Showing Constructions Details of Monitoring Well MW 644 and Adjacent Soil Gas Monitoring Points

Table 1. Initial Soil-Gas Compositions at Site SS-15

Monitoring Point	Depth (ft)	Oxygen (%)	Carbon Dioxide (%)	TPH (ppmv)
MPA	30	6.5	7.0	>20,000
	35	3.0	9.0	>20,000
	40	1.0	11	>20,000
MPB	30	2.5	9.0	>20,000
	35	2.0	9.5	>20,000
	40	1.0	9.5	>20,000
MPC	30	2.0	9.0	>20,000
	35	0.5	10	>20,000
	40	2.5	8.5	>20,000

completed, and the samples were sent to Alpha Analytical, Inc., in Sparks, Nevada. Samples were analyzed for BTEX, bulk density, moisture content, particle size, porosity, and TPH. The laboratory analytical report is provided in Appendix B.

3.5 LNAPL Recovery Testing

3.5.1 System Setup

The bioslurping pilot test system is a trailer-mounted mobile unit. The vacuum pump (Atlantic Fluidics Model A100, 7.5-hp liquid ring pump), filter box, oil/water separator, and required support equipment were carried to the test location on a trailer. The trailer was located near the monitoring well, the well cap was removed, a well seal was placed on the top of the well, and the slurper tube was lowered into the well. The slurper tube was attached to the vacuum pump. Different configurations of the well seal and the placement depth of the slurper tube allow for simulation of skimmer pumping, operation in the bioslurping configuration, or simulation of drawdown pumping. Extracted soil gas was discharged into the atmosphere. Extracted groundwater was treated by passing the recovered fluid through the filter box, the oil/water separators, and a settling tank. The groundwater was then discharged into the base's treatment plant.

A brief system startup test was performed prior to LNAPL recovery testing to ensure that all system components were working properly. The system checklist is provided in Appendix C. All site data and field testing information were recorded in a field notebook and then transcribed onto pilot test data sheets provided in Appendix D.

3.5.2 Initial Skimmer Pump Test

Prior to test initiation, depths to LNAPL and groundwater were measured. The liquid ring pump was used to conducted the skimmer pump test. The slurper tube was set at the oil/water interface. The drop tube was held in position by the well seal, and was positioned to leave the wellhead vented to the atmosphere (Figure 3). The liquid ring pump and oil/water separator were primed with known amounts of groundwater to ensure that any LNAPL or groundwater entering the system could be quantified. The flow totalizers for the LNAPL and aqueous effluent were zeroed, and the liquid ring pump was started at 11:48 am, 9 July 1996, to begin the second skimmer pump test. The pump vacuum was approximately 16″Hg and the vapor flowrate was approximately 32 scfm. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the bioslurper pump test. Test data sheets are provided in Appendix D.

3.5.3 Bioslurper Pump Test

Upon completion of the skimmer pump test, preparations were made to begin the bioslurper pump test. The LNAPL and groundwater depth were measured prior to any recovery testing. The slurper tube was set at the LNAPL/groundwater interface. The sanitary well seal was positioned inside the well, sealing the wellhead and allowing the pump to establish a vacuum in the well (Figure 4). A pressure gauge was installed at the wellhead to measure the vacuum inside the extraction well. The liquid ring pump was started at 12 pm, 11 July 1996, to begin the bioslurper pump test. The test was initiated approximately 0.5 hr after the skimmer pump test and was operated for 101.5 hr. Approximately 83 hr after test initiation, the liquid ring pump shut down for unknown reasons, but probably was due to thunderstorms in the area. The pump was down for approximately 4 hr. The pump test was initiated at full vacuum (19″Hg). After 5 hours, the vacuum was cut to 16″Hg and

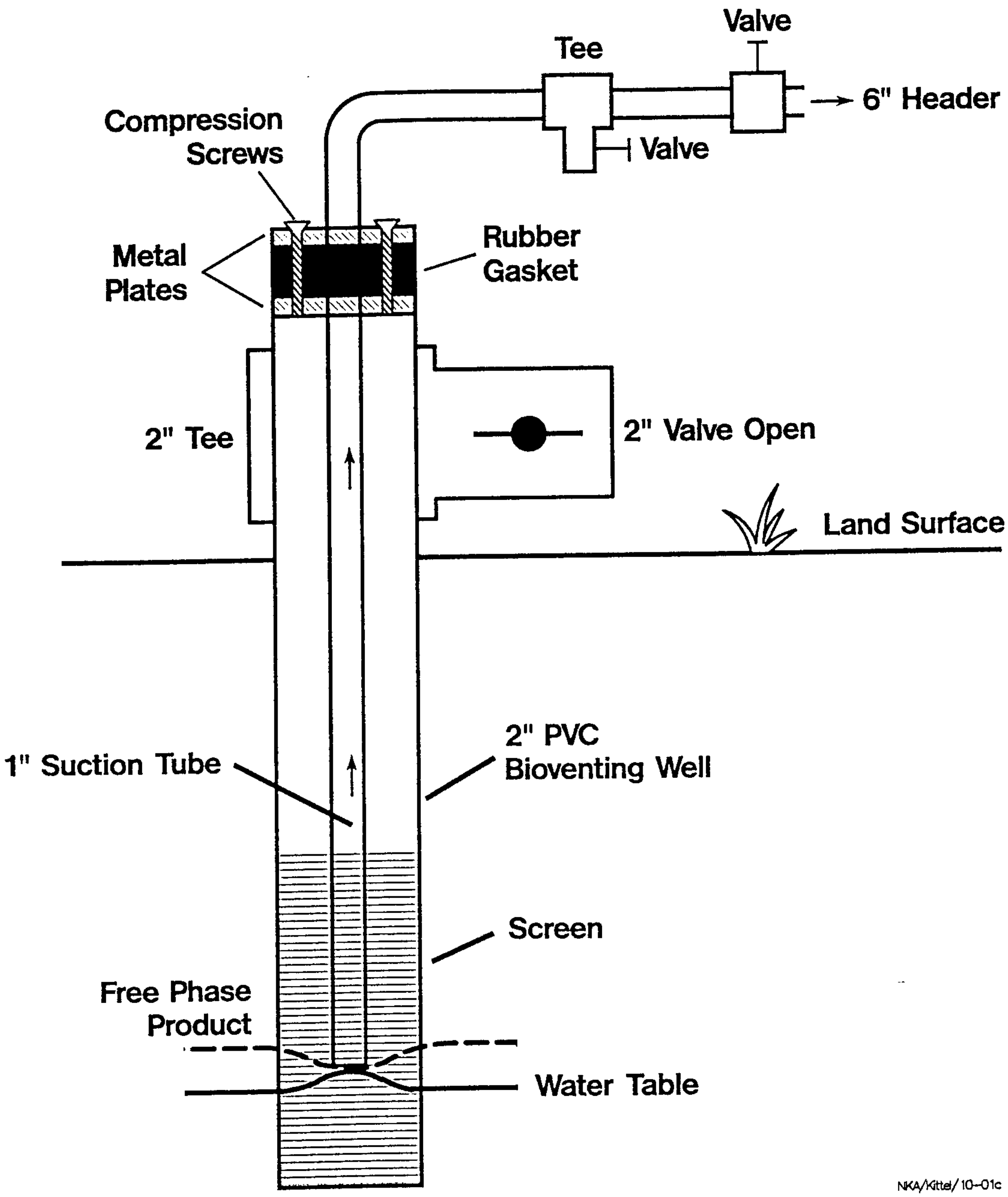

Figure 3. Drop Tube Placement and Valve Position During the Skimmer Pump Test

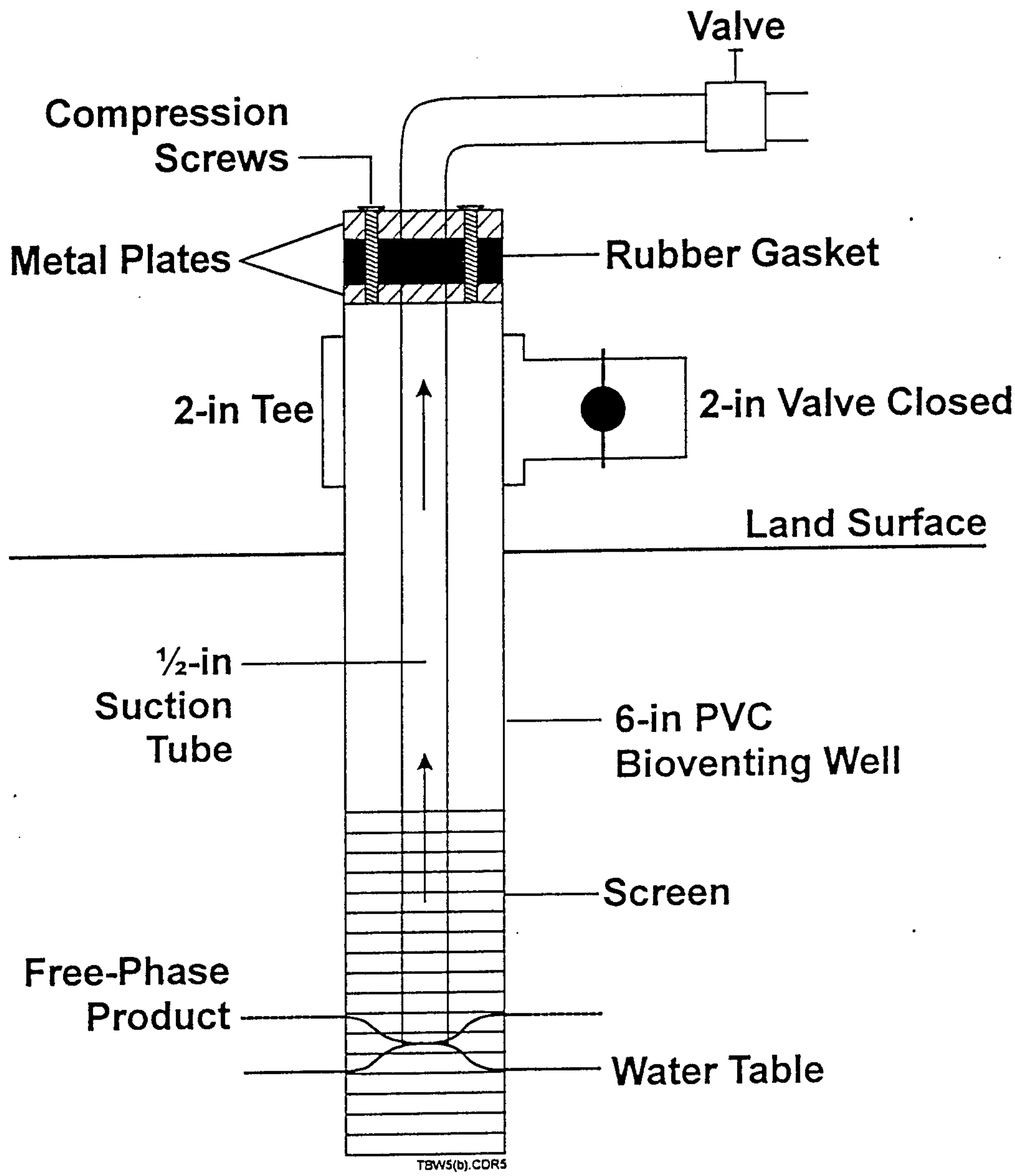

Figure 4. Drop Tube Placement and Valve Position During the Bioslurper Pump Test

after an additional 47.5 hr the pump was operated at full vacuum again (18"Hg). Vapor flowrates were approximately 9.5 scfm during the initial full vacuum portion of the pump test, 9.4 to 15 scfm during the reduced vacuum portion, and 14 to 26 scfm during the final full vacuum test. Well vacuums were approximately 26"H_2O during the initial full vacuum portion of the pump test, 12 to 13.5"H_2O during the reduced vacuum portion, and 21 to 22"H_2O during the final full vacuum test. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the bioslurper pump test. The data sheets are provided in Appendix D.

3.5.4 Second Skimmer Pump Test

Upon completion of the bioslurper pump test at monitoring well MW 644, preparations were made to begin the second skimmer pump test. Prior to test initiation, depths to LNAPL and groundwater were measured. The bioslurper system was used to conducted this skimmer pump test. The slurper tube was set at the oil/water interface. The drop tube was held in position by the well seal, and was positioned to leave the wellhead vented to the atmosphere. The liquid ring pump and oil/water separator were primed with known amounts of groundwater to ensure that any LNAPL or groundwater entering the system could be quantified. The flow totalizers for the LNAPL and aqueous effluent were zeroed, and the liquid ring pump was started at 4:15 pm, 15 July 1996, to begin the second skimmer pump test. The test was initiated approximately 0.5 hour after the bioslurper pump test and was operated continuously for 23 hours. The pump vacuum was approximately 15"Hg and the vapor flowrate was approximately 36 scfm. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the bioslurper pump test. Test data sheets are provided in Appendix D.

An LNAPL sample was collected from monitoring well MW 644 for analysis of BTEX and for boiling point fractionation and was labeled SHW-FP-1. The sample was sent to Alpha Analytical, Inc., in Sparks, Nevada for analysis.

3.5.5 Drawdown Pump Test

Upon completion of the second skimmer pump test, preparations were made to begin the drawdown pump test. Drawdown testing was conducted to determine if a cone of groundwater depression would enhance LNAPL recovery. The slurper tube was positioned 22 inches below the LNAPL/water interface measured prior to any recovery pump testing (Figure 5). The liquid ring pump was started at 8:10 am, 17 July 1996, to begin the drawdown pump test. The test was initiated approximately 17 hr after the second skimmer pump test was completed and was operated continuously for 28 hr. The pump vacuum was approximately 17"Hg and the vapor flowrate was approximately 26 scfm. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the drawdown pump test. Test data sheets are provided in Appendix D.

3.5.6 Off-Gas Sampling and Analysis

Three soil gas samples were collected during the pump tests at monitoring well MW 644. Samples SHW-AE-1 and SHW-AE-2 were collected during the bioslurper pump test at monitoring well MW 644 after 52 and 78 hr of operation, respectively. Sample SHW-AE-3 was collected during the second skimmer pump test following approximately 16 hr of operation. The samples were collected in Summa® canisters and sent under chain of custody to Air Toxics, Ltd., in Folsom, California, for analyses of BTEX and TPH, using EPA Method TO-3.

3.5.7 Groundwater Sampling and Analysis

Six groundwater samples were collected during the pump tests at monitoring well MW 644 and were labeled SHW-DC-1, SHW-DC-2, SHW-DC-3, SHW-DC-4, SHW-DC-5, and SHW-DC-6. Each sample was collected from the settling tank. Samples SHW-DC-1, SHW-DC-2, SHW-DC-3, and SHW-DC-4 were collected during the bioslurper pump test after approximately 52, 52, 78, and 78 hr of operation, respectively. Samples SHW-DC-5 and SHW-DC-6 were collected during the second skimmer pump test after approximately 16 hr of operation. Samples were collected in 40-mL septa vials containing hydrochloric acid (HC1) preservative. Samples were checked to ensure no headspace was present and were then shipped on ice and sent under chain of custody to Alpha Analytical, Inc., in Sparks, Nevada for analyses of BTEX and TPH (purgeable).

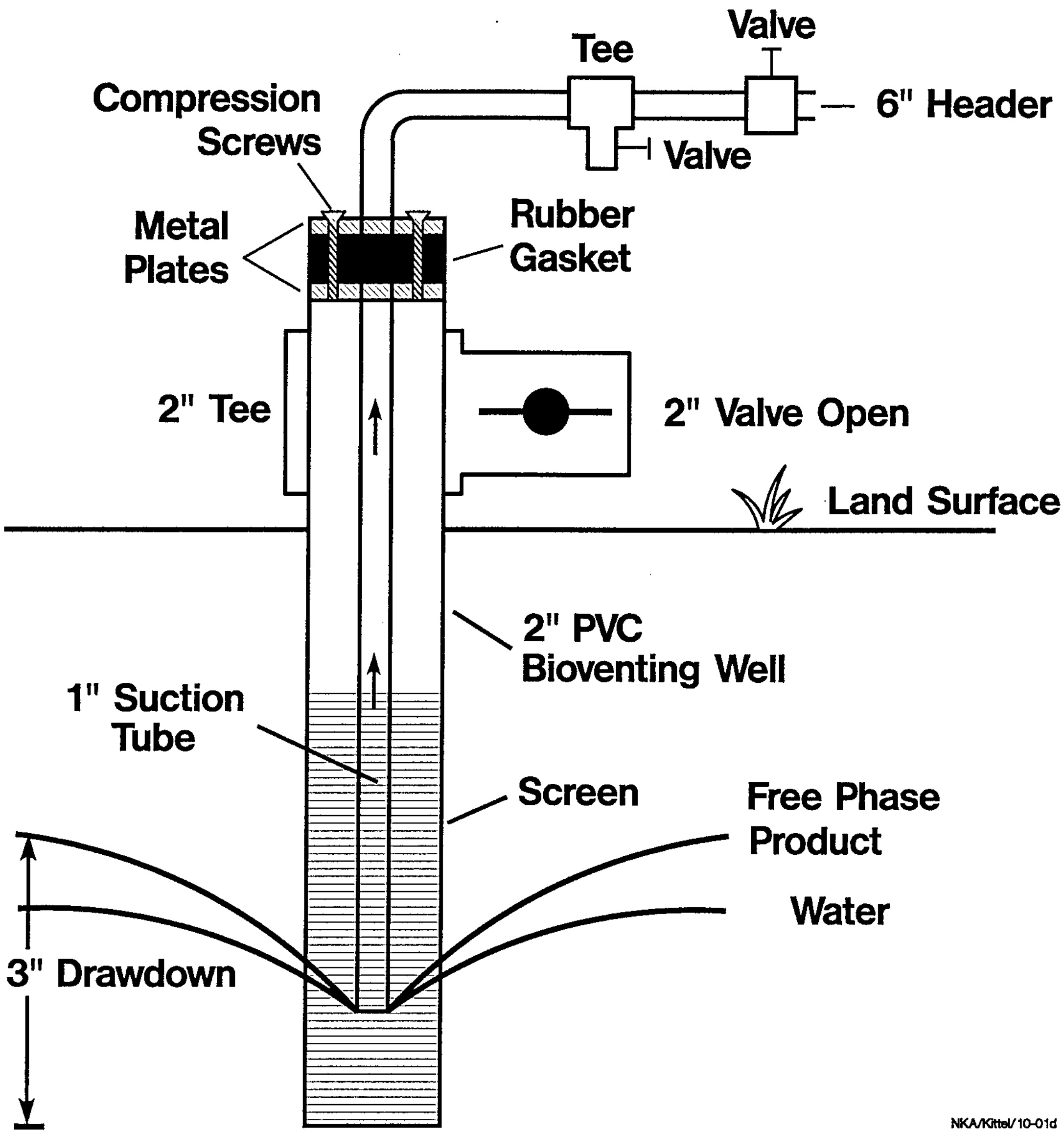

Figure 5. Drop Tube Placement and Valve Position for the Drawdown Pump Test

3.6 Bioventing Analyses

3.6.1 Soil Gas Permeability Testing

The soil gas permeability test data were collected during the bioslurper pump test at monitoring well MW 644. Before a vacuum was established in the extraction well, the initial soil gas pressures at the three installed monitoring points were recorded. The start of the bioslurper pump test created a steep pressure drop in the extraction well which was the starting point for the soil gas permeability testing. Soil gas pressures were measured at each of the three monitoring points at all depths to track the rate of outward propagation of the pressure drop in the extraction well. Soil gas pressure data were collected frequently during the first 20 minutes of the test. The soil gas pressures were recorded throughout the bioslurper pump test to determine the bioventing radius of influence. Test data are provided in Appendix E.

3.6.2 In Situ Respiration Testing

Air containing approximately 2% helium was injected into four monitoring points for approximately 21 hr beginning on 17 July 1996. The setup for the in situ respiration test is described in the Test Plan and Technical Protocol a Field Treatability Test for Bioventing (Hinchee et al., 1992). A ½-hp diaphragm pump was used for air and helium injection. Air and helium were injected through monitoring points SHW-MPA-30.0′, SHW-MPA-35.0′, SHW-MPA-40.0′, and SHW-MPD-16.0′. After the air/helium injection was terminated, soil gas concentrations of oxygen, carbon dioxide, TPH, and helium were monitored periodically. The in situ respiration test was terminated on 18 July 1996. Oxygen utilization and biodegradation rates were calculated as described in Hinchee et al. (1992). Raw data for these tests are presented in Appendix F.

Helium concentrations were measured during the in situ respiration test to quantify helium leakage to or from the surface around the monitoring points. Helium loss over time is attributable to either diffusion through the soil or leakage. A rapid drop in helium concentration usually indicates leakage. A gradual loss of helium along with a first-order curve generally indicates diffusion. As a rough estimate, the diffusion of gas molecules is inversely proportional to the square root of the molecular weight of the gas. Based on molecular weights of 4 for helium and 32 for oxygen, helium diffuses approximately 2.8 times faster than oxygen, or the diffusion of oxygen is 0.35 times the rate of helium diffusion. As a general rule, we have found that if helium concentrations at test completion are at least 50 to 60% of the initial levels, measured oxygen uptake rates are representative. Greater helium loss indicates a problem, and oxygen utilization rates are not considered representative.

4.0 RESULTS

This section documents the results of the site characterization, the comparative LNAPL recovery pump test, and other supporting tests conducted at Shaw AFB.

4.1 Baildown Test Results

Results from the baildown tests are presented in Tables 2 and 3. Baildown recovery tests provide a qualitative indication of the presence of mobile, free-phase LNAPL and recovery potential. Overall, the baildown recovery tests indicated a relatively high rate of LNAPL recovery into the wells. At monitoring well MW 644, LNAPL recovered to within 70% of initial levels by the end of the 4 hr baildown test. At monitoring well MW 634, LNAPL recovered to a level approximately 50% of the initial LNAPL thickness. Based on these results, pilot testing was initiated on monitoring well MW 644.

4.2 Soil Sample Analyses

Table 4 shows the TPH and BTEX concentrations measured in soil samples collected from Site SS-15. TPH and BTEX concentrations were very similar between samples with benzene below detection limits in both samples. TPH and BTEX concentrations averaged 385 mg/kg and 2.7 mg/kg, respectively. The results of the physical characterization and inorganic analysis of the soil are presented in Table 5. Soils were very permeable, with soils consisting primarily of sand.

Table 2. Baildown Test Results at Monitoring Well MW 634

Sample Collection Time	Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)
Initial Reading 7/8/96-1330			6.51
7/8/96-1358	51.36	50.71	0.65
7/8/96-1400	51.15	50.29	0.86
7/8/96-1402	50.89	49.81	1.08
7/8/96-1406	50.28	49.21	1.07
7/8/96-1409	50.01	48.99	1.02
7/8/96-1411	49.82	48.89	0.93
7/8/96-1414	49.45	48.63	0.82
7/8/96-1418	49.29	48.44	0.85
7/8/96-1422	49.16	48.21	0.95
7/8/96-1426	49.02	48.01	1.01
7/8/96-1431	48.88	47.79	1.09
7/8/96-1436	48.81	47.59	1.22
7/8/96-1441	48.77	47.31	1.46
7/8/96-1514	48.75	46.76	1.99
7/8/96-1549	48.81	46.41	2.40
7/8/96-1822	49.46	45.85	3.61

Table 3. Baildown Test Results at Monitoring Well MW 644

Sample Collection Time	Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)
Initial Reading 7/8/96-1430			4.34
7/8/96-1452	47.62	45.89	1.73
7/8/96-1454	47.55	45.81	1.74
7/8/96-1455	47.52	45.75	1.77
7/8/96-1456	47.42	45.65	1.77
7/8/96-1459	47.34	45.57	1.77
7/8/96-1502	47.25	45.43	1.82
7/8/96-1513	47.00	45.07	1.93
7/8/96-1518	46.95	44.96	1.99
7/8/96-1529	46.83	44.78	2.05
7/8/96-1601	46.81	44.46	2.35
7/8/96-1811	47.24	44.09	3.15

Table 4. TPH and BTEX Concentrations in Soil Samples

Parameter	Concentration (mg/kg)	
	SHW-S-1	SHW-S-2
TPH (Purgeable)	390	380
Benzene	<0.10	<0.10
Toluene	0.13	0.16
Ethylbenzene	0.28	0.33
Total Xylenes	1.8	2.5

Table 5. Physical Characterization of Soil Samples

Parameter		Sample	
		SHW-S-1	SHW-S-2
Moisture Content (%)		1.8	2.3
Porosity (%)		42.7	46.4
Density (g/cm^3)		1.52	1.42
Particle Size	Sand	98.1	NA
	Silt	1.9	NA
	Clay	0	NA

4.3 LNAPL Pump Test Results

4.3.1 Initial Skimmer Pump Test Results

A significant quantity of LNAPL was recovered during this test during 48 hr of continuous extraction during the skimmer pump test (Table 6). The initial LNAPL recovery rate was 23.5 gallons/day, which dropped to 14.5 gallons/day by the second day of testing. A total of approximately 390 gallons of groundwater was produced with an average production rate of 196 gallons/day. Results of LNAPL recovery versus time are shown in Figure 6.

4.3.2 Bioslurper Pump Test Results

LNAPL recovery was significantly greater than that observed during the skimmer pump test (Figure 6). Bioslurper testing was conducted for approximately four days, resulting in relatively high recovery on the first day (46 gallons/day), with a significant reduction in recovery by day 2 to 28 gallons/day. However, by day 3, LNAPL recovery rates increased to 37 gallons/day, and remained relatively constant for the remainder of the testing. This increase on day 3 corresponds to increasing the pump vacuum and a corresponding increase in vapor flowrate and well vacuum.

A total of 150 gallons of LNAPL and 1,240 gallons of groundwater was extracted, with daily average recovery rates of 38 gallons/day for LNAPL and 320 gallons/day for groundwater (Table 6). The LNAPL recovery rate versus time is shown in Figure 7.

Soil gas concentrations were measured during the bioslurper test at monitoring points adjacent to monitoring well MW 644 to determine if the vadose zone was being oxygenated via the bioslurper action. Unfortunately, results were inconclusive based on oxygen measurements, although soil gas permeability testing indicated that a radius of influence of approximately 40 ft could be achieved. In general, it is our experience that oxygenation will occur at monitoring points where a perceptible pressure change is measured.

4.3.3 Second Skimmer Pump Test

LNAPL recovery rates during the second skimmer pump test were similar to the initial skimmer pump test during approximately 23 hours of continuous pumping. Approximately 21 gallons

Table 6. Pump Test Results at Monitoring Well MW 644

Time (Days)	Recovery Rate (gallons/day)							
	Initial Skimmer Pump Test		Bioslurper Pump Test		Second Skimmer Pump Test		Drawdown Pump Test	
	LNAPL	Groundwater	LNAPL	Groundwater	LNAPL	Groundwater	LNAPL	Groundwater
1	24	180	46	320	22	190	31	240
2	15	210	28	240	NA	NA	28	230
3	NA	NA	37	350	NA	NA	NA	NA
4	NA	NA	36	250	NA	NA	NA	NA
5	NA	NA	42	340	NA	NA	NA	NA
Average	18	200	38	320	22	190	30	240
Total Recovery (gallons)	36.1	390	150	1,240	21.2	180	54.2	435

NA = Not applicable.

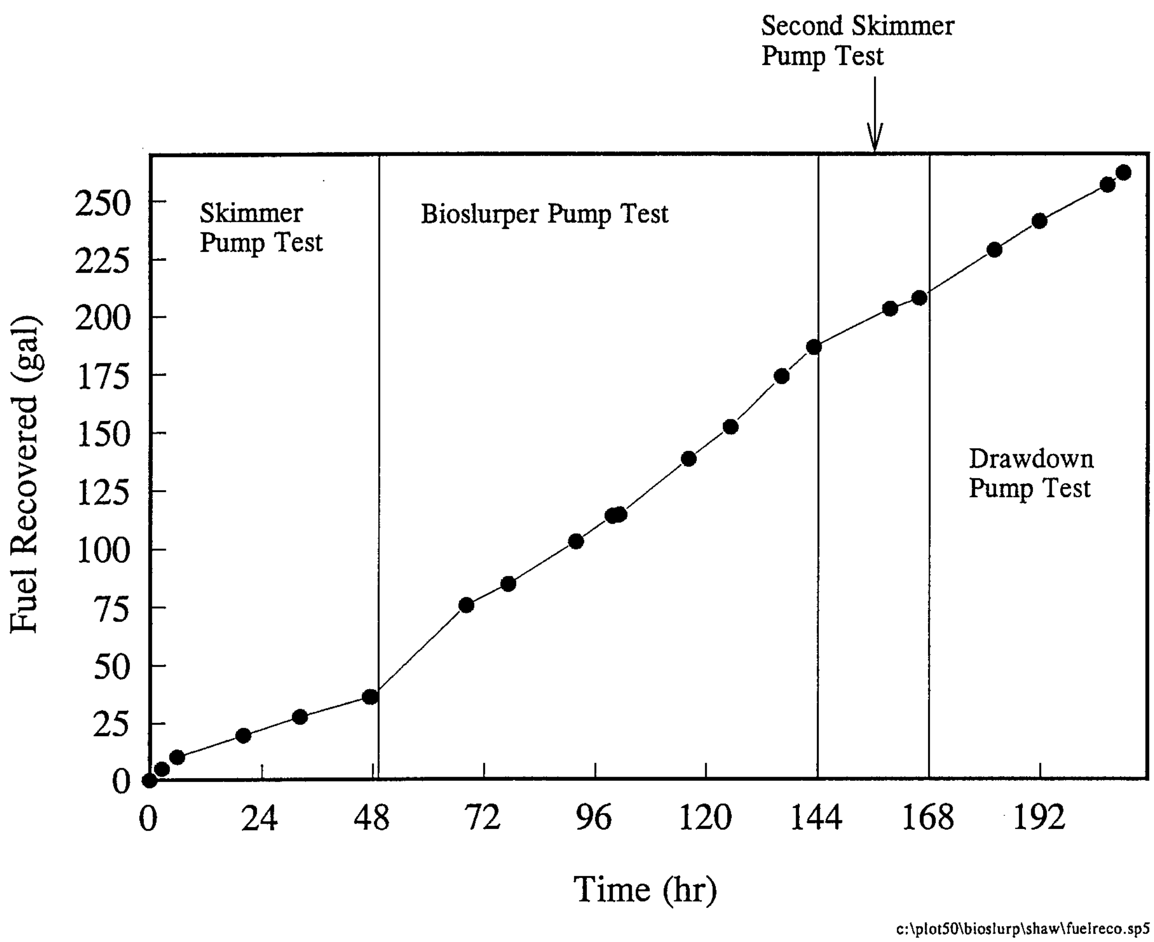

Figure 6. LNAPL Recovery Versus Time During Each Pump Test

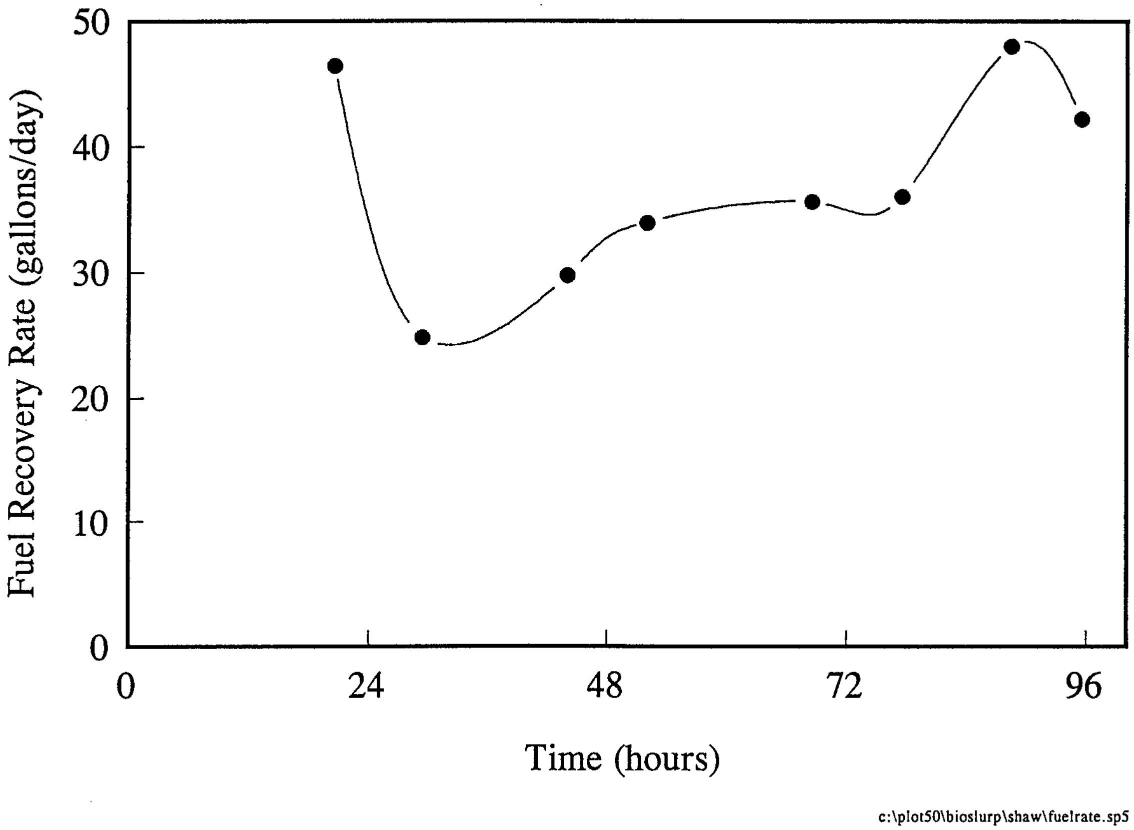

Figure 7. LNAPL Recovery Rate Versus Time During the Bioslurper Pump Test

of LNAPL and 180 gallons of groundwater were recovered during the second skimmer pump test, with daily average recovery rates of 22 and 190 gallons/day, respectively (Table 6). These results demonstrate that operation of the bioslurper system in the skimmer mode was an effective means of free-product recovery, although recovery rates are significantly lower than during bioslurping.

4.3.4 Drawdown Pump Test

Drawdown pump testing was conducted to determine if a cone of groundwater depression would enhance LNAPL recovery. The water table was depressed 22 inches below the static water table in monitoring well MW 644. Significant quantities of LNAPL were recovered, with average rates of 30 gallons/day and a total recovery of approximately 54 gallons (Table 6). Groundwater production rates were on the order of 240 gallons/day, with a total of approximately 440 gallons produced. These results demonstrate that the vacuum gradient maintained during the bioslurper test resulted in higher fluid recovery rates than the 22 inch-groundwater drawdown test.

4.3.5 Extracted Groundwater, LNAPL, and Off-Gas Analyses

Results of groundwater analyses are shown in Table 7. Contaminant concentrations were similar between the samples, with average TPH and total BTEX concentrations of 2.7 mg/L and 1.1 mg/L, respectively. The on-site water treatment equipment, consisting of a filter tank, oil/water separator, and clarification tanks, resulted in water effluent (2.3 to 3.0 mg/L total hydrocarbons) that is considered compatible with typical sanitary sewer discharge limits.

The results from the off-gas analyses are presented in Table 8. Given a flowrate of 12.5 scfm and using an average concentration of 12,500 ppmv TPH and 1,300 ppmv benzene, approximately 65 lb/day of TPH and 4.7 lb/day of benzene were emitted to the air. Thus, mass removal in the vapor phase is significant. Higher vapor mass removal rates are more often sustained at those sites where liquid product recovery is sustained. Sample SHW-AE-3 was collected during the second skimmer pump test and contaminant concentrations were approximately an order of magnitude higher than previously collected samples. There is no apparent reason for this difference, but may have been caused by a contaminant slug in the sample.

Emulsion

Table 7. BTEX and TPH Concentrations in Extracted Groundwater During Pump Tests

Parameter	Concentration (mg/L)		
	SHW-DC-1/2[1]	SHW-DC-3/4[1]	SHW-DC-5/6[1]
TPH (purgeable)	3.0	2.9	2.3
Benzene	0.062	0.076	0.11
Toluene	0.31	0.30	0.32
Ethylbenzene	0.11	0.097	0.10
Total Xylenes	0.64	0.61	0.63

Collected from 1500 gal Tank

1 Samples SHW-DC-1, -3, and -6 were analyzed for BTEX only. Samples SHW-DC-2, -4, and -6 were analyzed for TPH only.

Table 8. BTEX and TPH Concentrations in Off-Gas During the Bioslurper Pump Test

Parameter	Concentration (ppmv)		
	SHW-AE-1	SHW-AE-2	SHW-AE-3[1]
TPH as jet fuel	13,000	12,000	130,000
Benzene	1,900	700	11,000
Toluene	1,900	1,100	14,000
Ethylbenzene	1,200	590	9,800
Total Xylenes	2,400	1,200	20,000

1 Off-gas sample was not collected during bioslurper operations.

Skimmer

The composition of LNAPL is shown in Tables 9 and 10 in terms of BTEX concentrations and distribution of C-range compounds, respectively. The distribution of C-range compounds also is shown graphically in Figure 8.

4.4 Bioventing Analyses

4.4.1 Soil Gas Permeability and Radius of Influence

The radius of influence is calculated by plotting the log of the pressure change at a specific monitoring point versus the distance from the extraction well. The radius of influence is then defined as the distance from the extraction well where 0.10 inch of H_2O can be measured. Based on this definition, the radius of influence during the bioslurper pump test at MW 644 was approximately 40 ft (Figure 9).

4.4.2 In Situ Respiration Test Results

Results from the in situ respiration test are presented in Table 11. Oxygen utilization rates were relatively high, ranging from 0.025 to 21 $\%O_2$/hr. Biodegradation rates ranged from 0.41 to 340 mg/kg-day. Biodegradation rates were significantly higher at the deeper depths than at a depth of 16 ft bgl. These results indicate that biodegradation in these locations is significant and that bioventing is feasible at this site.

5.0 DISCUSSION AND CONCLUSIONS

The main objective of the field pilot test at Site SS-15, Shaw AFB was to determine if LNAPL recovery is feasible and to select the most effective method of LNAPL recovery.

Baildown recovery tests were conducted at monitoring wells MW 634 and MW 644. Baildown recovery tests provide a qualitative indication of the presence of mobile, free-phase LNAPL and recovery potential. Overall, the baildown recovery tests indicated a relatively high rate of LNAPL recovery into the wells. At monitoring well MW 644, LNAPL recovered to within 70% of initial levels by the end of the 4 hr baildown test. At monitoring well MW 634, LNAPL recovered to

Table 9. BTEX Concentrations in LNAPL

Compound	Concentration (mg/kg)
Benzene	1,300
Toluene	7,100
Ethylbenzene	3,300
Total Xylenes	17,000

Table 10. C-Range Compounds in LNAPL

C-Range	Percentage of Total (%)
<C9	49.93
C10	13.04
C11	11.19
C12	10.35
C13	7.98
C14	4.69
C15	1.92
C16	0.54
>C17	0.36

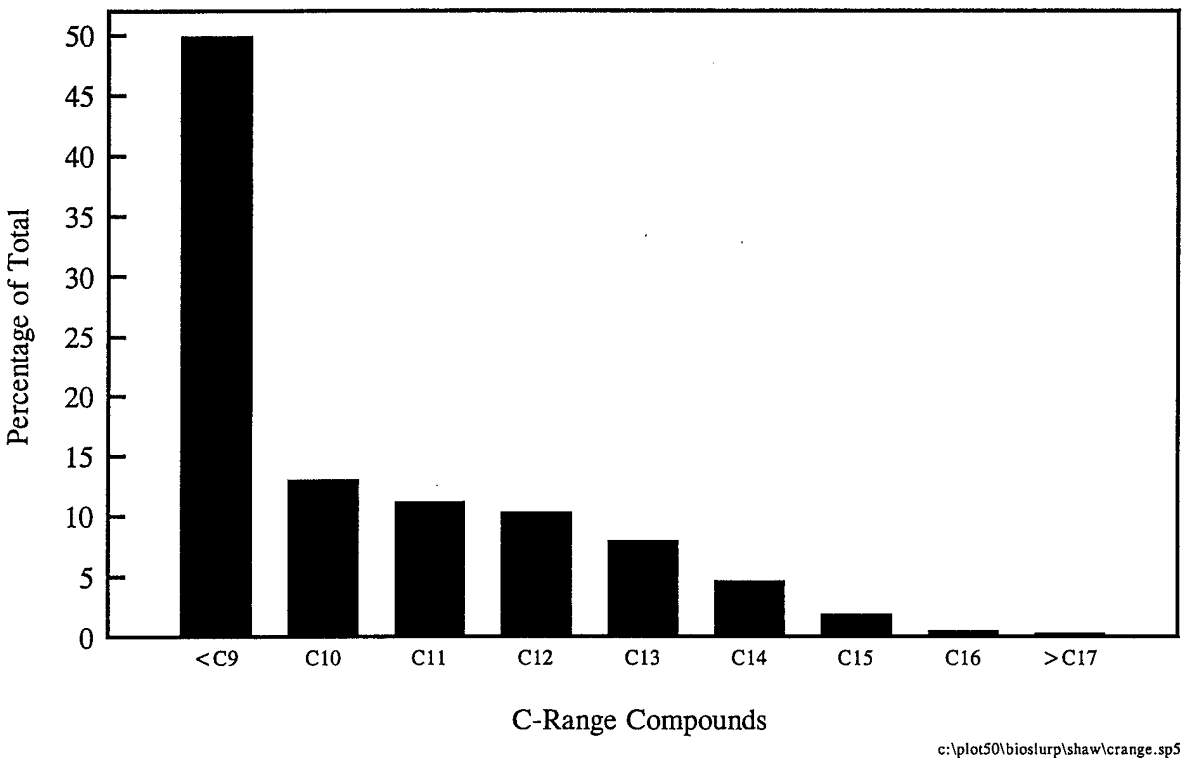

Figure 8. Distribution of C-Range Compounds in LNAPL

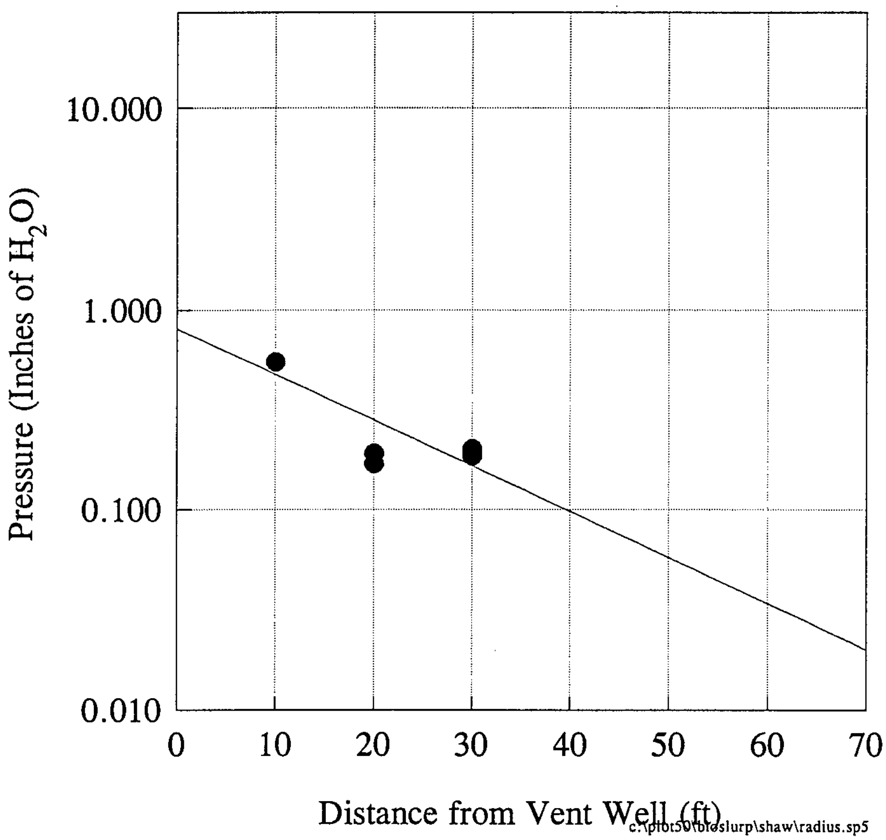

Figure 9. **Radius of Influence Determination Using Soil Gas Pressure Change Versus Distance From Extraction Well**

Table 11. In Situ Respiration Test Results

Monitoring Point	Oxygen Utilization Rate (%/hr)	Biodegradation Rate (mg/kg-day)
MPA-30′	2.4	39
MPA-35′	5.6	91
MPA-40′	21	340
MPD-16′	0.025	0.41

a level approximately 50% of the initial LNAPL thickness. Based on these results, pilot testing was initiated on monitoring well MW 644.

Direct pumping tests were conducted at monitoring well MW 644. Skimmer pump testing was conducted at monitoring well MW 644 in a continuous extraction mode for two days. A significant quantity of LNAPL was recovered during this pump test. The initial LNAPL recovery rate was 23.5 gallons/day, which dropped to 14.5 gallons/day by the second day of testing. A total of approximately 390 gallons of groundwater was produced with an average production rate of 200 gallons/day. LNAPL recovery was significantly greater during the bioslurper pump test than that observed during the skimmer pump test. Bioslurper testing was conducted for approximately four days, resulting in relatively high recovery on the first day (46 gallons/day), with a significant reduction in recovery by day 2 to 28 gallons/day. However, by day 3, LNAPL recovery rates increased to 37 gallons/day, and remained relatively constant for the remainder of the testing. This increase on day 3 corresponds to increasing the pump vacuum and a corresponding increase in vapor flowrate and well vacuum. A total of 150 gallons of LNAPL and 1,240 gallons of groundwater was extracted, with daily average recovery rates of 38 gallons/day for LNAPL and 320 gallons/day for groundwater.

LNAPL recovery rates during the second skimmer pump test were similar to the initial skimmer pump test during approximately 23 hours of continuous pumping. Approximately 21 gallons of LNAPL and 180 gallons of groundwater were recovered during the second skimmer pump test, with daily average recovery rates of 22 and 190 gallons/day, respectively. These results demonstrate that operation of the bioslurper system in the skimmer mode was an effective means of free-product recovery, although recovery rates are significantly lower than during bioslurping.

Drawdown pump testing was conducted to determine if a cone of groundwater depression would enhance LNAPL recovery. The water table was depressed 22 inches below the static water table in monitoring well MW 644. Significant quantities of LNAPL were recovered, with average rates of 30 gallons/day and a total recovery of approximately 54 gallons. Groundwater production rates were on the order of 240 gallons/day, with a total of approximately 440 gallons produced. These results demonstrate that the vacuum gradient maintained during the bioslurper test resulted in higher fluid recovery rates than the 22 inch-groundwater drawdown test.

Bioslurping also promotes mass removal in the form of in situ biodegradation via bioventing and soil gas extraction. Vapor phase mass removal is the result of soil gas extraction as well as volatilization that occurs during the movement of LNAPL free product through the extraction network. Given a flowrate of 12.5 scfm and using an average concentration of 12,500 ppmv TPH and 1,300 ppmv benzene, approximately 65 lb/day of TPH and 4.7 lb/day of benzene were emitted to the air. Thus, mass removal in the vapor phase is significant. Higher vapor mass removal rates are more often sustained at those sites where liquid product recovery is sustained.

The initial soil gas profiles at the site displayed oxygen-deficient, carbon dioxide-rich, high total volatile hydrocarbon vapor conditions at depths from 30 to 40 ft bgl. These conditions indicate that natural biodegradation of residual petroleum hydrocarbons has occurred, but is limited by oxygen availability. Soil gas concentrations were measured during the bioslurper test at monitoring points adjacent to monitoring well MW 644 to determine if the vadose zone was being oxygenated via the bioslurper action. Unfortunately, results were inconclusive based on oxygen measurements, although soil gas permeability testing indicated that a radius of influence of approximately 40 ft could be achieved. In general, it is our experience that oxygenation will occur at monitoring points where a perceptible pressure change is measured. In situ biodegradation rates 0.025 of 21 to mg/kg-day were measured at four different locations. Based on the radius of influence of 40 ft and a hydrocarbon-impacted soil thickness of 40 ft, mass removal rates via biodegradation are on the order of 0.43 to 370 lbs of hydrocarbon per day. Thus, mass removal rates via biodegradation could be more significant than the vapor phase removal rates measured during the bioslurper test. These results indicate that bioventing is feasible at this site. Air injection bioventing is preferable over bioslurping and soil vapor extraction with respect to the elimination of hydrocarbon vapor emissions.

In summary, the on-site testing at Site SS-15, Shaw AFB, included the direct testing of gravity-driven and vacuum-driven LNAPL free product recovery techniques, bioventing, physical sampling, and tests relevant to soil vapor extraction. Liquid phase recovery was sustainable during all pump tests, with the highest recoveries during bioslurping. The in situ respiration test and vadose zone radius of influence testing demonstrate that bioventing may be feasible at this site. Bioslurping appears to be a suitable recovery technique for this site.

6.0 REFERENCES

Battelle, 1995. Test Plan and Technical Protocol for Bioslurping. Report prepared by Battelle Columbus Operations for the U.S. Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas.

Hinchee, R.E., S.K. Ong, R.N. Miller, D.C. Downey, and R. Frandt. 1992. Test Plan and Technical Protocol for a Field Treatability Test for Bioventing (Rev. 2). Report prepared by Battelle Columbus Operations, U.S. Air Force Center for Environmental Excellence, and Engineering Sciences, Inc., for the U.S. Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas.

APPENDIX A

SITE-SPECIFIC TEST PLAN FOR BIOSLURPER FIELD ACTIVITIES AT SHAW AFB, SOUTH CAROLINA

SITE-SPECIFIC TEST PLAN FOR BIOSLURPER TESTING AT SHAW AIR FORCE BASE, SOUTH CAROLINA (A002)
CONTRACT NO. F41624-94-C-8012

DRAFT

to

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May 3, 1995

by

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DRAFT

U.S. Air Force
Brooks AFB

May 3, 1995

1.0 INTRODUCTION

The Air Force Center for Environmental Excellence is conducting a nationwide application of an innovative technology for free-product recovery and soil bioremediation. The technology tested in the Bioslurper Initiative is vacuum-enhanced free-product recovery/bioremediation (bioslurping). The field test and evaluation are intended to demonstrate the initial feasibility of bioslurping by measuring system performance in the field. System performance parameters, mainly free-product recovery, will be determined at numerous sites. Field testing will be performed at many sites to determine the effects of different organic contaminant types and concentrations and different geological conditions on bioslurping effectiveness.

Plans for the field test activities are presented in two documents. The first is the overall test plan and technical protocol for the entire program, titled *Test Plan and Technical Protocol for Bioslurping* (Battelle, 1995). The overall plan is supplemented by plans specific to each test site. The concise site-specific plans effectively communicate regulatory background to Base personnel.

The overall test plan and protocol was developed as a generic plan for the Bioslurper Initiative to improve the accuracy and efficiency of test plan preparation. The field program requires installation and operation of the bioslurping system supported by a wide variety of site characterization, performance monitoring, and chemical analysis activities. The basic methods to be applied from site to site do not change. Preparation and review of the overall plan allows efficient documentation and review of the basic approach to the test program. Peer and regulatory review were performed for the overall plan to ensure the credibility of the overall program.

This letter report is the site-specific plan for application of bioslurping at Shaw Air Force Base, South Carolina. It was prepared based on site-specific information received by Battelle from Shaw AFB and other pertinent site-specific information to support the generic test plan.

Site-specific information for Shaw AFB included data for the POL Depot and surrounding area. An initial review of the data indicates that the southeastern corner of the depot is the most likely candidate for the bioslurper pilot test. Specifically, Well #COE-T22, near Building 103, and Well #MW-506, at the underground storage tank (UST) Site SS-15, appear to be good candidates for the bioslurper field test. If the southeastern corner of the POL site is found unsuitable for testing, the area south of the POL depot is a viable alternative.

2.0 SITE DESCRIPTION

The site of interest is the southeastern corner of the POL Depot. The organic liquid contaminant is JP-4 jet fuel, and the primary source of contamination appears to be the underground storage tank farms. Figure 1 shows the POL Depot site, including the monitoring wells in the vicinity and the extent of the free-product plume. Table 1 summarizes the subsurface fuel thickness measurement data for all wells located in the area around the POL Depot. From these data, the wells that are most likely to yield significant amounts of free product have been identified. Well #COE-T2 and Well #MW-506 had the greatest fuel thickness when measurements were taken January 16, 1992; their measurements were 3.14 and 2.62 ft, respectively. When the July 15, 1993, measurement was taken, these thicknesses had reduced to 1.88 and 1.65 ft, but were still the largest amounts of free product measured in the site wells. This decrease in fuel thickness most likely is the result of an interim free-product/groundwater recovery system that has been in operation since May 18, 1991.

Site characterization (see Section 3.2) will begin with the wells residing in the free-product plume (see Figure 1) within the POL Depot. If these wells prove unsuitable, or if site logistics prevent their use, the wells south of the POL Depot will be used. Possible candidate wells for the bioslurper pilot test are Well #MW-617 and Well #MW-634. Information on the well construction data of possible candidate wells is located in Appendix A.

The principal organic liquid contaminant in the candidate test site at Shaw AFB is JP-4 jet fuel. Previous analyses have shown that the principal constituents at the site are benzene, toluene, ethylbenzene, and xylenes (BTEX). The BTEX concentration in groundwater in the area of Well #COE-T2 and Well #MW-506 is approximately 5 ppm, with a benzene concentration of approximately 1.4 ppm.

Polycyclis aromatic hydrocarbons (PAHs) also have been found to be present at the site. Previous analyses of the groundwater at the site have revealed the presence of four PAHs – acenaphthene, naphthalene, methylnaphthalene, and fluorene. However, all previous analyses of the site soils and groundwater have indicated that the main source of contamination at the site is the free-product plume of JP-4 jet fuel.

3.0 PROJECT ACTIVITIES

The following field activities are planned for the bioslurper pilot test at Shaw AFB. Additional details about the activities are presented in the *Test Plan and Technical Protocol for Bioslurping* (Battelle, 1995). As appropriate, specific sections in the generic Bioslurping Protocol assessment are referenced. Table 2 shows the schedule of activities for the Bioslurper Initiative at Shaw AFB.

3.1 Mobilization to the Site

After the site-specific test plan is approved, Battelle staff will mobilize equipment. All equipment will be mobilized to Shaw AFB by Battelle staff. The exact mobilization date will be confirmed with the Base Point of Contact (POC) as far in advance of fieldwork as is possible. The Battelle POC will provide the Base POC with information on each Battelle employee who will be on site.

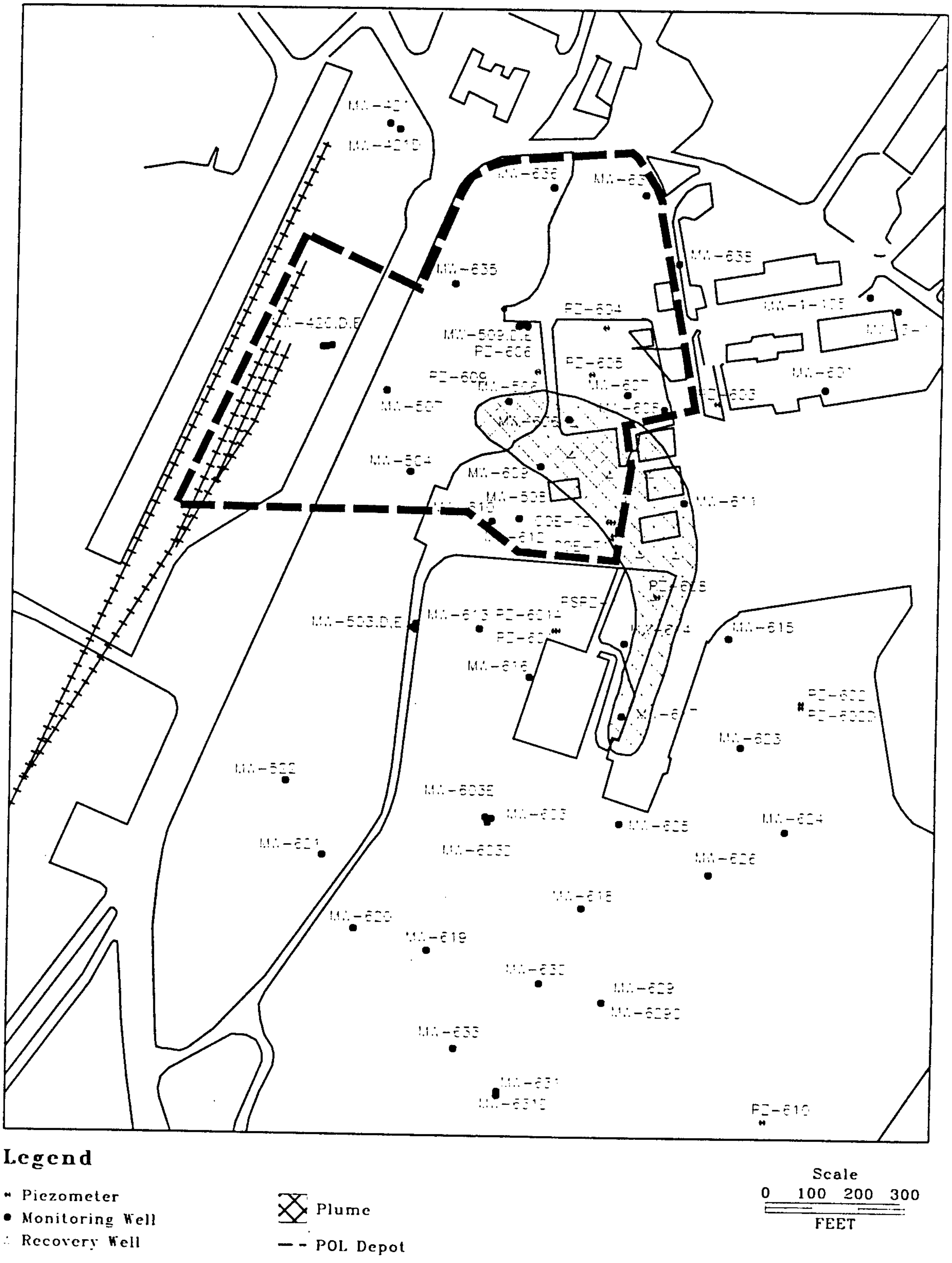

Figure 1. Location of Areas of Interest for Bioslurper Testing at Shaw AFB

Table 1. Subsurface Apparent Fuel Thickness for Wells in or Near the POL Depot.

WELL ID	Easting (feet)	Northing (feet)	12/16/92 Water Level Elevation (feet)	12/16/92 Product Thickness (feet)	02/02/93 Water Level Elevation (feet)	02/02/93 Product Thickness (feet)	04/06/93 Water Level Elevation (feet)	04/06/93 Product Thickness (feet)	06/04/93 Water Level Elevation (feet)	06/04/93 Product Thickness (feet)	7/15/93 Water Level Elevation (feet)	7/15/93 Product Thickness (feet)
COE-T1	2156293	351283	210.4	0.61	211.4	0.57	211.7	0.68	212.5	0.63	—	—
COE-T2	2156296	351321	210.5	1.88	211.3	1.70	210.6	2.03	213.2	3.14	—	—
COE-T3	2156288	351321	218.9	0.02	220.4	0.01	220.0	0.01	218.7	0.02	—	—
MW -1-105	2156863	351777	213.5	0.00	214.4	0.00	215.3	0.00	215.6	0.00	—	—
MW-2-105	2156843	351804	215.1	0.00	216.0	0.00	216.9	0.00	217.2	0.00	—	—
MW-3-105	2156904	351775	214.3	0.00	215.3	0.00	216.1	0.00	216.4	0.00	—	—
MW-420	2155673	351690	214.9	0.00	215.4	0.00	216.4	0.00	217.0	0.00	—	—
MW-420D	2155666	351689	—	—	—	—	—	—	174.7	0.00	—	—
MW-420E	2155684	351692	—	—	—	—	170.1	0.00	—	—	173.7	0.00
MW-421	2155800	352160	218.9	0.00	219.2	0.00	220.2	0.00	220.5	0.00	169.4	0.00
MW-421D	2155821	352148	—	—	—	—	—	—	174.0	0.00	—	—
MW-501	2157985	349332	208.8	0.00	211.1	0.00	211.3	0.00	209.8	0.00	173.3	0.00
MW-502	2156862	348849	209.1	0.00	211.6	0.00	212.2	0.00	211.7	0.00	—	—
MW-503	2155866	351090	210.2	0.00	212.2	0.00	213.0	0.00	213.3	0.00	—	—
MW-503D	2155871	351085	—	—	—	—	—	—	180.7	0.00	—	—
MW-503E	2155872	351098	—	—	—	—	172.3	0.00	172.4	0.00	179.7	0.00
MW-504	2155855	351425	212.0	0.00	—	—	213.9	0.00	214.2	0.00	170.4	0.00
MW-505	2156309	351304	DRY	DRY	DRY	0.85	210.6	1.88	DRY	0.00	—	—
MW-506	2156197	351540	211.8	2.62	212.6	2.61	212.3	1.67	214.0	1.65	—	—
MW-507	2155802	351597	213.2	0.00	213.9	0.00	215.0	0.00	215.5	0.00	—	—
MW-508	2156092	351326	210.8	0.00	211.6	0.00	212.7	0.00	213.1	0.00	—	—
MW-509	2156104	351736	213.4	0.00	214.0	0.00	215.2	0.00	215.6	0.00	—	—
MW-509D	2156095	351738	174.5	0.00	174.9	0.00	176.5	0.00	176.1	0.00	—	—
MW-509E	2156085	351736	—	—	—	—	173.3	0.00	172.0	0.00	174.4	0.00
MW-601	2156750	351606	212.7	0.00	213.5	0.00	214.5	0.00	214.8	0.00	168.9	0.00
MW-602	2157378	351448	213.8	0.00	215.0	0.00	216.2	0.00	216.3	0.00	—	—
MW-603	2156042	350681	206.6	0.00	207.9	0.00	209.4	0.00	209.9	0.00	—	—
MW-603D	2156028	350684	183.2	0.00	183.9	0.00	185.3	0.00	185.3	0.00	—	—
MW-603E	2156033	350672	—	—	—	—	174.5	0.00	173.0	0.00	184.3	0.00
MW-604	2157431	350216	208.3	0.00	210.4	0.00	211.1	0.00	212.3	0.00	171.0	0.00
MW-605	2159983	350133	206.6	0.00	209.2	0.00	209.5	0.00	208.6	0.00	—	—
MW-606	2156066	351576	212.4	0.00	212.1	0.00	214.2	0.00	214.6	0.00	—	—
MW-607	2156324	351592	212.0	2.50	212.8	2.48	211.2	3.27	211.4	0.00	—	—
MW-608	2156404	351561	211.8	1.50	211.5	1.44	212.7	1.15	213.3	0.00	—	—
MW-609	2156138	351438	211.3	0.00	212.3	0.00	213.2	0.00	212.3	0.00	—	—
MW-610	2156032	351320	211.1	0.00	211.8	0.00	212.9	0.02	213.2	0.00	—	—
MW-611	2156451	351363	210.6	1.52	211.5	1.04	212.0	0.34	212.6	0.34	—	—
MW-612	2156113	351255	210.0	0.00	210.7	0.00	211.8	0.00	212.2	0.00	—	—
MW-613	2156009	351088	209.1	0.00	210.0	0.00	211.3	0.00	211.6	0.00	—	—
MW-614	2156325	351060	208.6	0.00	209.7	0.00	210.8	0.00	210.6	0.00	—	—
MW-615	2156551	351072	209.7	0.00	210.7	0.00	211.7	0.00	211.8	0.00	—	—
MW-616	2156119	350986	207.8	0.01	208.9	0.00	210.3	0.00	210.4	0.00	—	—
MW-617	2156322	350904	207.1	1.63	208.2	1.25	208.4	1.01	209.5	0.97	—	—
MW-618	2156241	350490	205.7	0.00	207.1	0.00	208.6	0.00	209.0	0.00	—	—
MW-619	2155906	350396	206.4	0.00	207.7	0.00	209.3	0.00	209.7	0.00	—	—
MW-620	2155749	350441	207.0	0.00	208.2	0.00	209.8	0.00	210.3	0.00	—	—
MW-621	2155680	350598	—	—	209.1	0.00	210.8	0.00	211.4	0.00	—	—
MW-622	2155600	350757	209.0	0.00	209.9	0.00	211.7	0.00	212.4	0.00	—	—
MW-623	2156580	350838	—	—	208.3	0.00	209.5	0.00	209.7	0.00	—	—
MW-624	2156678	350657	—	—	208.0	0.00	209.3	0.00	209.5	0.00	—	—

Table 1. Subsurface Apparent Fuel Thickness for Wells in or Near the POL Depot. (Continued)

WELL ID	Easting (feet)	Northing (feet)	12/16/92 Water Level Elevation (feet)	12/16/92 Product Thickness (feet)	02/02/93 Water Level Elevation (feet)	02/02/93 Product Thickness (feet)	04/06/93 Water Level Elevation (feet)	04/06/93 Product Thickness (feet)	06/04/93 Water Level Elevation (feet)	06/04/93 Product Thickness (feet)	7/15/93 Water Level Elevation (feet)	7/15/93 Product Thickness (feet)
MW-625	2156320	350672	205.8	0.00	207.1	0.01	208.5	0.00	208.9	0.00	—	—
MW-626	2156516	350564	248.1	0.00	207.3	0.00	208.7	0.00	208.9	0.00	—	—
MW-627	2155714	349785	—	—	—	0.01	205.8	0.00	207.4	0.00	—	—
MW-628	2155965	349670	—	—	—	—	207.9	0.00	208.3	0.00	—	—
MW-629	2156288	350287	—	—	206.7	0.00	208.2	0.00	208.5	0.00	—	—
MW-630	2156152	350327	—	—	206.9	0.00	208.5	0.00	208.8	0.00	207.4	0.00
MW-631	2156062	350087	—	—	206.2	0.00	208.0	0.00	208.4	0.00	—	—
MW-632	2155394	349581	—	—	201.7	0.00	203.6	0.00	204.2	0.00	—	—
MW-633	2155967	350185	—	—	207.0	0.00	208.6	0.00	209.0	0.00	—	—
MW-634	2156008	349838	—	—	203.8	9.61	2.0	1.41	208.0	1.34	—	—
MW-635	2155946	351824	215.0	0.00	0.0	0.00	216.8	0.00	217.2	0.00	—	—
MW-636	2156157	352029	215.7	0.00	0.0	0.00	217.5	0.00	218.0	0.00	—	—
MW-637	2156357	352014	215.2	0.00	0.0	0.00	216.9	0.00	217.3	0.00	—	—
MW-638	2156432	351870	—	—	0.0	0.00	216.6	0.00	216.9	0.00	—	—
MW-639	2155644	349216	—	—	—	—	—	—	213.1	0.00	—	—
MW-640	2155084	349275	—	—	—	—	—	—	214.5	0.00	—	—
OBPZ-1	2155593	349705	190.1	0.00	191.4	0.00	193.3	0.00	193.7	0.00	190.2	0.00
OBPZ-IA	2155591	349709	171.7	0.00	172.4	0.00	173.9	0.00	173.1	0.00	—	—
OBPZ-1B	2155595	349700	190.5	0.00	191.9	0.00	193.8	0.00	194.1	0.00	171.0	0.00
OBPZ-2	2155642	349719	199.9	0.00	202.1	0.00	204.4	0.00	205.2	0.00	—	—
OBPZ-3	2155688	349733	200.7	0.00	202.8	0.00	205.2	0.00	205.9	0.00	—	—
PSPZ-I	2156220	351100	208.7	0.00	209.6	0.00	210.6	0.00	210.9	0.00	—	—
PSPZ-2	2156275	351364	210.6	0.45	211.1	0.41	212.0	0.39	212.7	0.38	—	—
PZ-601	2156180	351086	208.6	0.00	2.0	0.00	210.6	0.00	210.9	0.00	—	—
PZ-601A	2156173	351085	208.7	0.00	209.7	0.04	210.8	0.02	211.1	0.02	—	—
PZ-602	2156708	350925	208.0	0.00	209.3	0.00	210.4	0.00	210.6	0.00	—	—
PZ-602D	2156708	350935	180.0	0.00	180.8	0.00	181.33	0.00	181.9	0.00	—	—
PZ-603	2156518	351575	212.0	0.00	212.7	0.00	213.8	0.00	214.0	0.00	180.0	0.00
PZ-604	2156275	351734	213.0	0.00	213.6	0.02	214.8	0.00	215.0	0.00	—	—
PZ-605	2156246	351635	DRY	DRY	DRY	DRY	DRY	DRY	—	—	—	—
PZ-606	2156128	351640	212.7	0.48	213.1	0.34	214.5	0.00	214.9	0.00	—	—
PZ-607	2157472	349782	208.2	0.00	210.6	0.00	211.1	0.00	209.2	0.00	—	—
PZ-608	2156395	351161	209.3	1.74	210.3	1.58	210.1	0.59	213.0	0.33	—	—
PZ-609	2155023	349421	201.7	0.00	203.0	0.00	206.6	0.00	207.8	0.00	—	—
PZ-610	2156641	350037	206.1	0.00	207.8	0.00	209.1	0.00	209.2	0.00	—	—
PZ-611	2155919	348736	211.1	0.00	213.5	0.00	214.5	0.00	214.5	0.00	—	—
PZ-612	2156051	351771	213.7	0.00	214.3	0.00	215.5	0.00	215.9	0.00	—	—
PZ-891	2156299	351292	210.3	0.00	211.1	0.00	212.0	0.00	—	—	—	—

Table 2. Schedule of Bioslurper Test Activities

Pilot Test Activity	Schedule
Mobilization	day 1-2
Site Characterization	day 2-3
Baildown Tests and Product/Groundwater Interface Monitoring	
Soil-Gas Survey (limited)	
Monitoring Point (MP) Installation (3 MPs)	
Soil Sampling (TPH, BTEX, physical characteristics)	
System Installation	day 2-3
Test Startup	day 3
Skimmer Test (2 days)	day 3-4
Bioslurper Vacuum Extraction (4 days)	day 6-9
Soil-Gas Permeability Testing	day 6
Skimmer Test (continued)	day 10
In Situ Respiration Test — air/helium injection	day 10
In Situ Respiration Test — monitoring	day 11-16
Drawdown Pump Test (2 days)	day 11-12
Demobilization/Mobilization	day 13-14

3.2 Site Characterization Tests

3.2.1 Baildown Tests

The baildown test is the primary test for selection of the bioslurper test well. Baildown tests will be performed at wells that contain measurable thicknesses of light, nonaqueous-phase liquid (LNAPL) to estimate the LNAPL recovery potential at those particular wells. In most cases, the well exhibiting the highest rate of LNAPL recovery will be selected for the bioslurper extraction well. Table 3 presents the volume of fuel that would be present in a 1-foot measured thickness for vaious size wells. Detailed procedures for the baildown tests are provided in Section 5.6 of the generic Bioslurping Protocol.

Table 3. Volumes Per Unit Length for Common Well Casing Diameters

Nominal Pipe Size	Gal/ft (Schedule 40 Pipe)	Gal/ft (Schedule 80 Pipe)
2.0	0.174	0.153
3.0	0.384	0.343
4.0	0.661	0.597
6.0	1.50	1.35

3.2.2 Soil-Gas Survey (Limited)

A small-scale soil-gas survey will be conducted to identify the best location for installation of the bioslurping system. The soil-gas survey will be conducted in areas where historical site data indicate the highest contamination levels. In Table 1, the heavily contaminated wells appear in bold type. The area around these wells will be surveyed to select the locations for installation of soil-gas monitoring points. Soil-gas surveying will be concentrated around areas that exhibit the following characteristics.

1. Soil vapor from the site will exhibit high total petroleum hydrocarbon (TPH) concentrations (10,000 ppm or greater).

2. Soil vapor will contain relatively low oxygen concentrations (between 0% and 2%).

3. Soil vapor will have relatively high carbon dioxide concentrations (depending on soil type, between 2% and 10% or greater).

To obtain further information about the soil-gas survey, consult Section 5.2 of the generic Bioslurping Protocol.

3.2.3 Monitoring Point Installation

Monitoring points must be installed to determine the radius of influence that the free-product recovery system has on vadose zone contaminated soils. A general arrangement of the bioslurping well and monitoring points is shown in Figure 2.

Upon conclusion of the initial soil-gas survey and baildown tests, at least three soil-gas monitoring points will be installed to measure soil-gas changes that occur during the operation of the bioslurper. These monitoring points should be located in highly contaminated soils within the free-phase plume and should be positioned to allow detailed monitoring of the in situ changes in soil-gas composition caused by the bioslurper system. The components of soil-gas monitoring points are shown in Figure 3. A conceptual arrangement for soil-gas monitoring points in Well #COE-2T at the UST area in the POL Depot is presented in Figure 4. Information on monitoring point installation can be found in Section 4.2.1 of the generic Bioslurping Protocol.

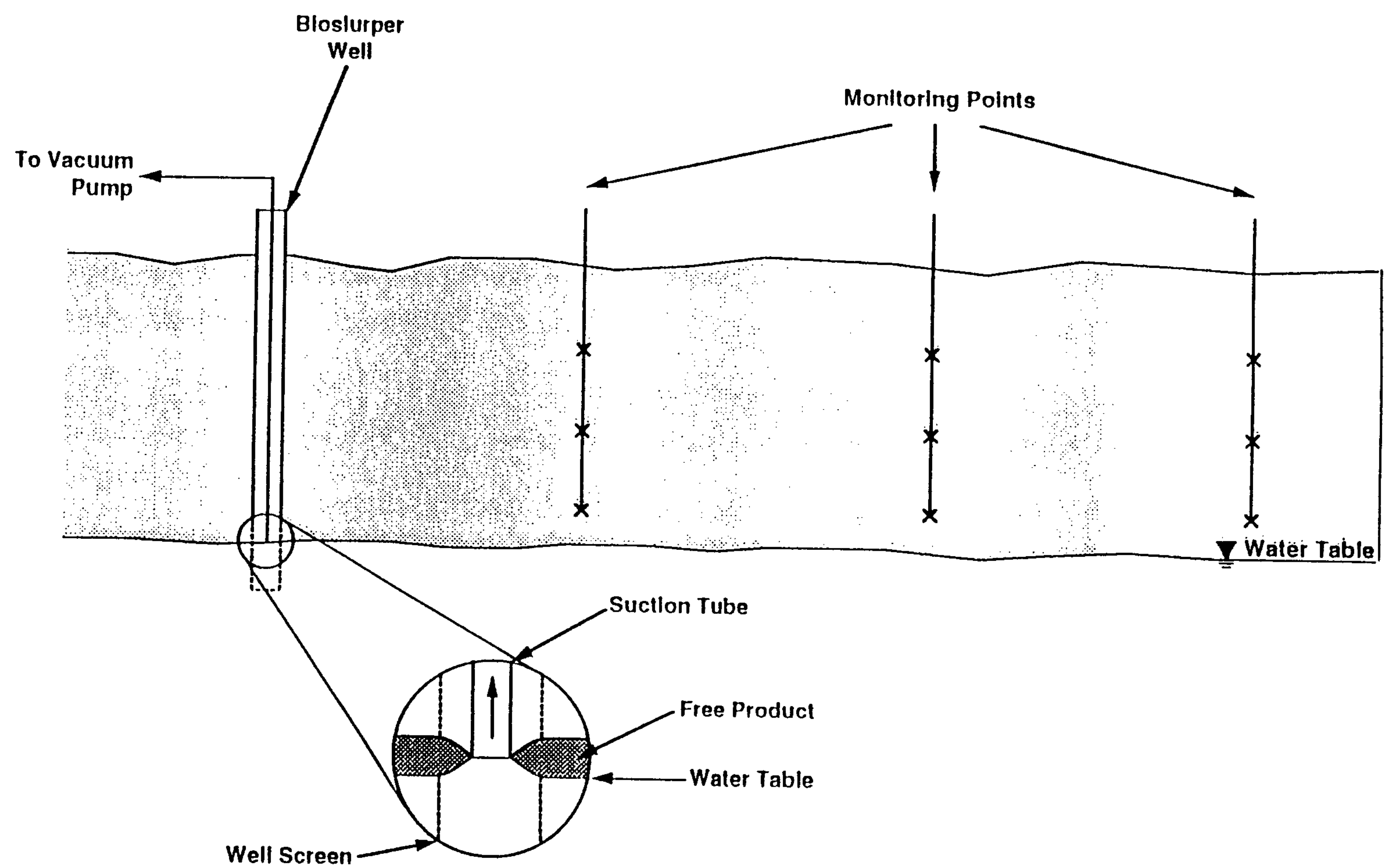

Figure 2. General Bioslurper Well and Monitoring Point Arrangement

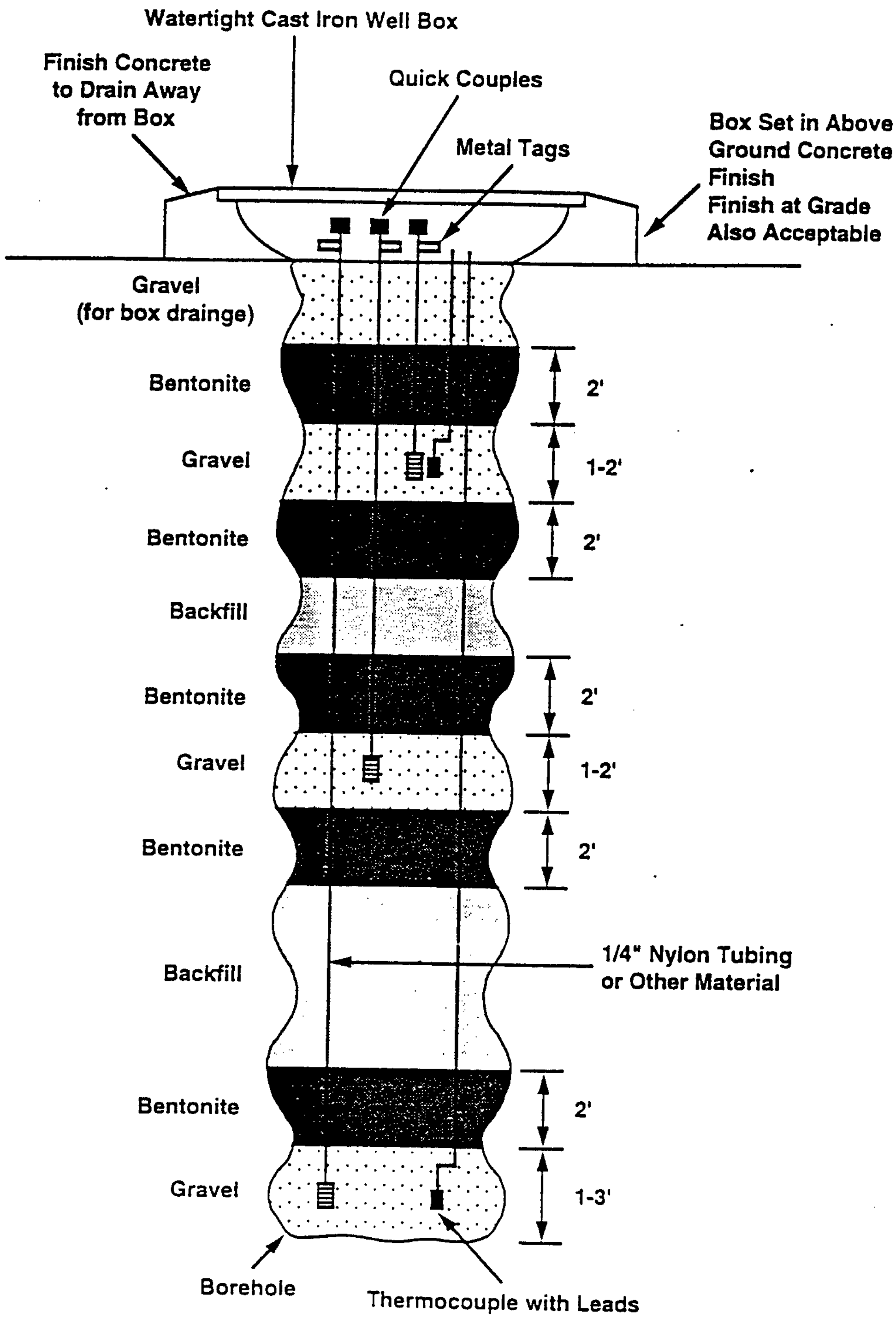

Figure 3. Diagram of a Typical Bioslurper Soil-Gas Monitoring Point

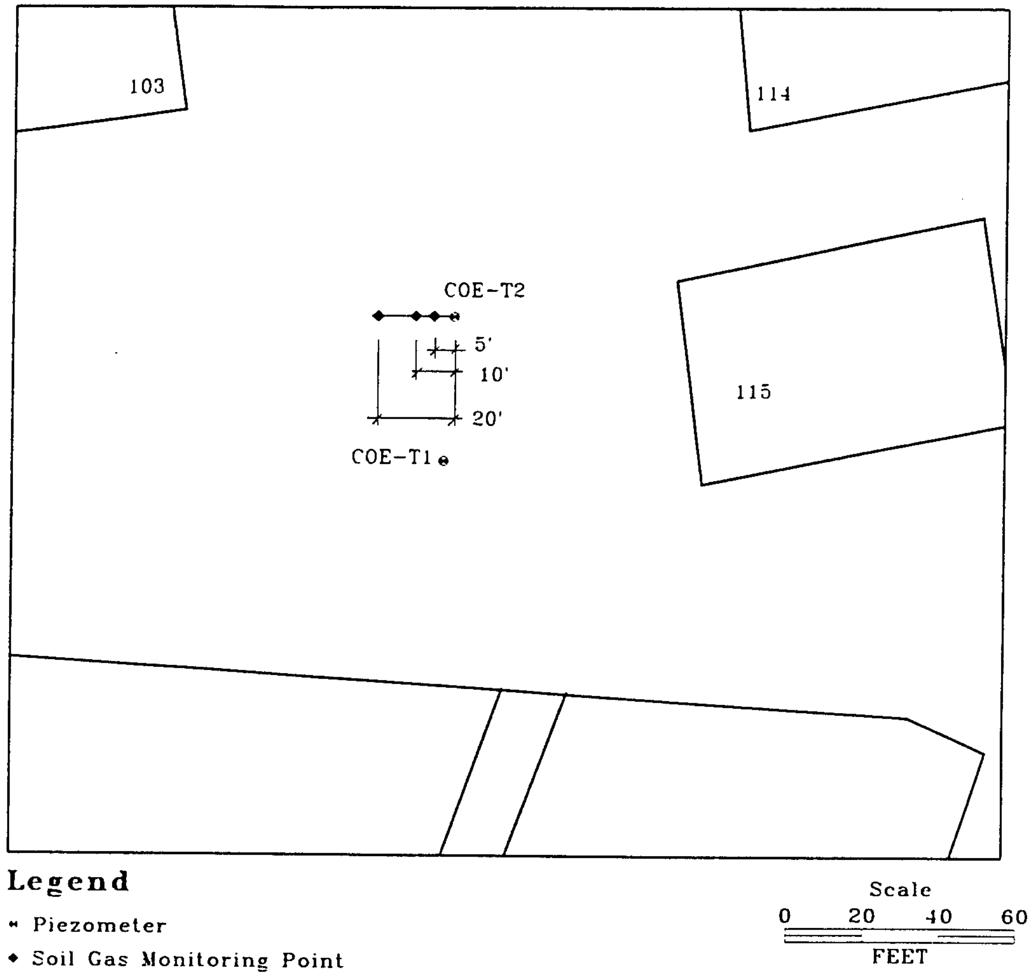

Figure 4. Conceptual Arrangement for Soil-Gas Monitoring Points at UST Area.

3.2.4 Soil Sampling

Soil samples will be collected to determine the physical and chemical composition of the soil near the bioslurper test site. Soil samples will be collected from the boreholes advanced for monitoring point installation at two or three locations at the site chosen for the bioslurper test. Generally, samples will be collected from the capillary fringe over the free product.

Soil samples will be analyzed for particle-size distribution, bulk density, porosity, moisture content, BTEX, and TPH. Section 5.5.1 of the generic Bioslurping Protocol will be consulted for information on the field measurements and sample collection procedures for soil sampling.

3.3 Bioslurper System Installation and Operation

Once the well to be used for the bioslurper test installation at Shaw AFB has been identified, the bioslurper pump and support equipment will be installed and the pilot test will be initiated.

3.3.1 System Setup

After the preliminary site characterization has been completed and the bioslurper candidate well has been selected, the previously shipped equipment will be mobilized from the holding facility to the test site, and the bioslurper system will be assembled. Figure 5 shows a flow diagram of the bioslurper process. Figure 6 is a generic diagram of the bioslurper extraction well that will be installed at Shaw AFB.

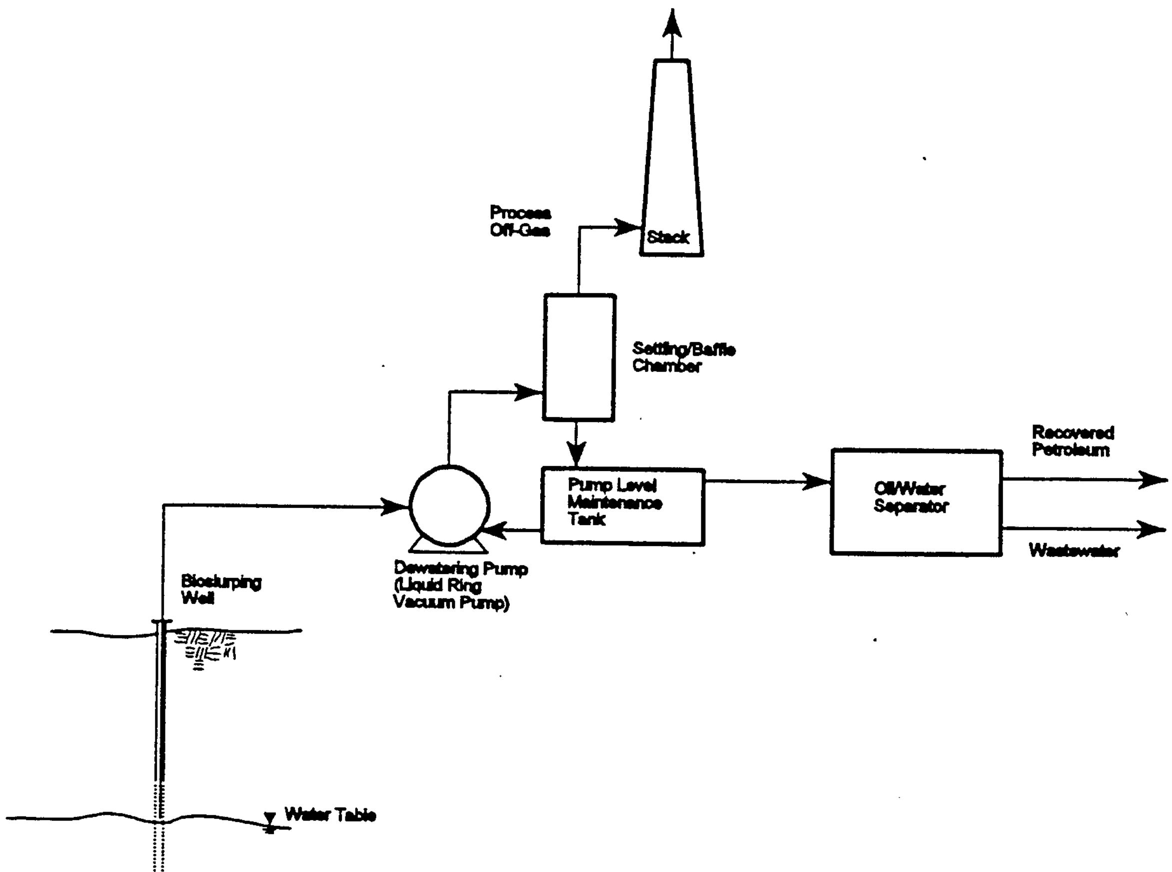

Figure 5. Bioslurper Process Flow

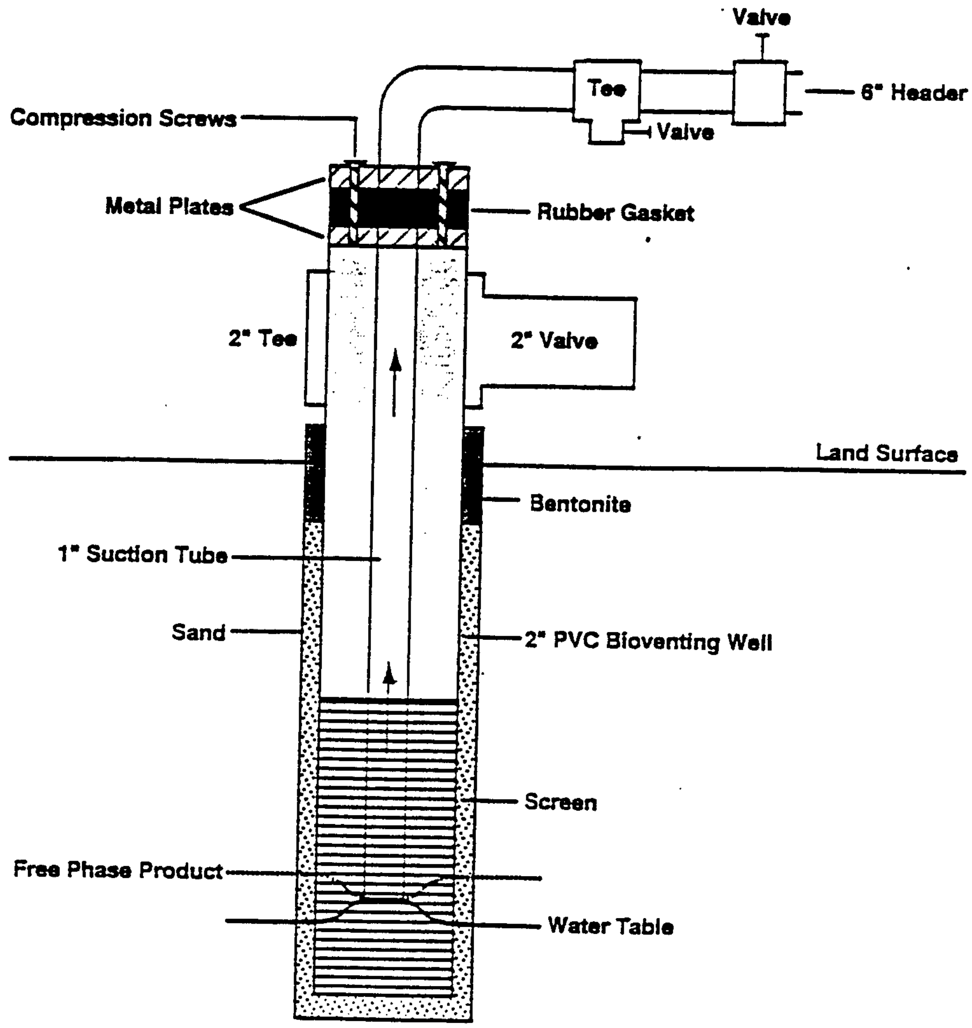

Figure 6. Diagram of a Typical Bioslurper Well

Before the LNAPL recovery tests are initiated, all relevant baseline field data will be collected and recorded. These data will include soil-gas concentrations, initial soil-gas pressures, the depth to groundwater, and the LNAPL thickness. Ambient soil and all atmospheric conditions (e.g., temperature, humidity, barometric pressure) also will be recorded. All emergency equipment (i.e., emergency shutoff switches and fire extinguishers) will be installed and checked for proper operation at this time.

A clear, level area near the well selected for the bioslurper test installation will be identified for the 20′ × 10′ flatbed trailer that holds the equipment required for bioslurper system operation. For more information on bioslurper system installation, consult Section 6.0 of the generic Bioslurping Protocol.

3.3.2 System Shakedown

A brief startup test will be conducted to ensure that the system is constructed properly and operates safely. All system components will be checked for problems and/or malfunctions. A checklist will be provided to document the system shakedown.

3.3.3 System Startup and Test Operations

After installation is complete and the bioslurper system is confirmed to be operating properly, the LNAPL recovery tests will be started. The Bioslurper Initiative has been designed to evaluate the effectiveness of bioslurping as an LNAPL recovery technology relative to conventional gravity-driven LNAPL recovery technologies. The Bioslurper Initiative includes three separate LNAPL recovery tests: (1) a skimmer simulation test, (2) a vacuum-assisted bioslurper test, and (3) a groundwater drawdown LNAPL recovery test. The three recovery tests are described in detail in Section 7.3 of the generic Bioslurping Protocol.

The bioslurper system operating parameters that will be measured during operation are vapor discharge, aqueous effluent, LNAPL recovery volume rates, vapor discharge volume rates, and groundwater discharge volume rates. Vapor monitoring will consist of continuous on-line monitoring of TPH supplemented by two samples collected for detailed laboratory analysis. A total of two samples of aqueous effluent will be collected for analysis of BTEX and TPH content. Recovered LNAPL volume will recorded using an in-line flow-totalizing meter. The off-gas discharge volume will be measured using a calibrated pitot tube, and groundwater discharge volume will recorded using an in-line flow-totalizing meter. Section 8.0 of the generic Bioslurping Protocol describes process monitoring of the bioslurper system.

3.3.4 Soil-Gas Permeability Test

A soil-gas permeability test will be conducted concurrently with startup of the vacuum-assisted bio-slurper operation. Soil-gas permeability data will support the process of estimating the vadose zone radius of influence of the bioslurper system. Soil-gas permeability results also will aid in determining the number of wells required if it is decided to treat the site with a large-scale bioslurper system. The soil-gas permeability test method is described in Section 5.7 of the generic Bioslurping Protocol.

3.3.5 In Situ Respiration Test

The oxygen utilization rate will be used to estimate the biodegradation rate at the site. An in situ respiration test will be conducted after completion of the bioslurper operating tests. The in situ respiration testing will involve injection of air/helium injection into selected soil-gas monitoring points followed by monitoring changes in concentration of oxygen, carbon dioxide, petroleum hydrocarbons, and helium in soil-gas near the injection point. Measurement of the soil-gas composition typically will be conducted at 2, 4, 6, and 8 hours and then every 4 to 12 hours for about 2 days. Timing of the tests will be adjusted based on oxygen-use rate. If oxygen depletion occurs rapidly, more frequent monitoring will be required. If oxygen depletion is slow, less frequent readings will be acceptable. Further information on the procedures and data collection for in situ respiration testing is given in Section 5.8 of the generic Bioslurping Protocol.

3.3.6 Extended Testing

The Air Force has the option of extending the operation of the bioslurper system for up to 6 months if LNAPL recovery rates are promising. If extended testing is to be performed, the Air Force will need to provide electrical power for long-term operation of the bioslurper pump. Disposition of all generated wastes and routine operation and maintenance of the system will be the Air Force's responsibility. Battelle will provide technical support during the extended testing operation.

3.4 Demobilization

Once all necessary tests have been completed at the Shaw AFB site, the equipment will be disassembled by Battelle staff. The equipment then will be moved back to a holding facility, where it will remain until its next destination is determined. Battelle staff will receive this information and will be responsible for shipment of the equipment to the next site before departing from Shaw AFB.

4.0 BIOSLURPER SYSTEM DISCHARGE

4.1 Vapor Discharge Disposition

Battelle expects that the operation of the bioslurper test system at the Shaw AFB site will require a waiver or a point source air release registration and may require some additional permits. However, due to the short duration of the bioslurper pilot test, it can be assumed that concentration of TPH released to the atmosphere will be approximately 65 lb TPH/day. This value is based on the average TPH discharge level at two bioslurper test sites (Wright-Patterson AFB and Travis AFB) that are contaminated with the same type of jet fuel as that found at the Shaw POL site. The value may vary depending on the TPH concentration of the soil gas and the permeability of the soil. The discharge of benzene is estimated to be less than 1 lb/day.

The data for the TPH and benzene discharge levels at four previous bioslurper sites are presented in Table 4. The large TPH discharge level at Travis AFB is partially due to the extraction rate of the vapors. This extraction rate is the maximum rate a 3-hp pump will achieve and should be lower at Shaw AFB due to the permeability of the soils. The vapor stream generated by the bioslurper system may be discharged directly to the atmosphere because of the short duration of the test and the low concentration levels of TPH and benzene in the stream.

Table 4. Benzene and TPH Discharge Levels at Previous Bioslurper Test Sites

Site Location	Fuel Type	Extraction Rate (scfm)	Benzene (ppmv)	TPH (ppmv)	Benzene Discharge (lb/day)	TPH Discharge (lb/day)
Wright-Patterson AFB	Jet Fuel	3	nd	595	0.0	1.0
Bolling AFB (Site #1)	No. 2 Fuel Oil	4	0.2	153	0.0003	0.009
Bolling AFB (Site #2)	Gasoline	21	370	70,000	2.3	470.1
Andrews AFB	No. 2 Fuel Oil	8	16	2,000	0.001	0.2
Travis AFB	Jet Fuel	20	100	10,800	0.58	126.4

nd = not detected

To ensure the safety and regulatory compliance of the bioslurper system, vapor discharge samples (TPH, O_2, and CO_2) will be collected periodically throughout the bioslurper pilot test, and field soil-gas screening instruments will be used to monitor vapor discharge concentration variability. The volume of vapor discharge will be monitored daily using air flow instruments. If state regulatory requirements will not permit the expected amount of organic vapor discharge to the atmosphere, the Base POC should inform AFCEE and Battelle so that alternative plans can be made prior to mobilization to the site. Table 5 presents information typically required to complete an air release registration form.

Table 5. Air Release Summary Information

Data Item	Air Release Information
Contractor Point of Contact	Jeff Kittel, (614) 424-6122
Contractor address	Battelle, 505 King Avenue, Columbus, OH 43201
Estimated total quantity of petroleum product to be recovered	TBD
Description of petroleum product to be recovered	JP-4 jet fuel
Planned date of test start	TBD
Test duration	9 days (active pumping)
Maximum expected VOC concentration in air	~65 lb/day (64 lb TPH, < 1.0 lb benzene)
Maximum total quantity of VOC release	~65 lb/day
Expected contaminants in air release	TPH, benzene (<0.2 mg/L)
Expected quantity of fuel use (for electrical generator)	125 gal
Type of fuel used	Gasoline and diesel fuel
Stack height above ground level	10 ft

4.2 Aqueous Influent/Effluent Disposition

The flowrate of groundwater pumped by the bioslurper will be less than 5 gpm. However, in South Carolina it may be necessary to obtain a groundwater pumping waiver or registration permit. If one is required, the Base POC will inform Battelle of the necessary steps in obtaining the waiver or permit.

Operation of the bioslurper system will generate an aqueous waste discharge that will be passed through an oil/water separator. The intention of Battelle staff will be to dispose of the wastewater by discharge directly to the Base wastewater treatment facility. If existing Base wastewater channels can be used, no National Pollutant Discharge Elimination System (NPDES) or other water discharge permits will be required.

4.3 Free-Product Recovery Disposition

The bioslurper system will recover free-phase product from the pilot tests performed at Shaw AFB. Free product recovered by the bioslurping tests will be turned over to the Base for disposal and/or recycling. The volume of free product recovered from the Base will not be known until the tests have been performed. The maximum recovery rate for this system is 5 gpm, but the actual rate of LNAPL recovery likely will be much lower.

5.0 SCHEDULE

The schedule for the bioslurper fieldwork at Shaw AFB will depend on approval of the project test plans. Battelle will determine a definitive schedule as soon as possible after approval is received. Battelle will have two to three staff members on site for approximately 2 weeks to conduct all necessary pilot testing. At the conclusion of the field testing at Shaw AFB, all staff will return their Base passes. Battelle staff will remove all bioslurper field testing equipment from the Base before they leave the site.

6.0 PROJECT SUPPORT ROLES

This section outlines some of the major functions of personnel from Battelle, Shaw AFB, and AFCEE during the bioslurper field test.

6.1 Battelle Activities

Battelle is responsibility in the Bioslurper Initiative at Shaw AFB will be to supply all the necessary staff and equipment to perform all the tests on the bioslurper system. Battelle also will provide technical support in the areas of water and vapor discharge permitting, digging permits, staff support during the extended testing period, and any other technical areas that need to be addressed.

6.2 Shaw AFB Support Activities

To support the necessary field tests at Shaw AFB, the Base must be able to provide the following:

1. Any digging permits and utility clearances that need to be obtained prior to the initiation of the fieldwork. Any underground utilities should be clearly marked to reduce the chance of utility damage and/or personal injury during soil-gas probe and possible well installation. Battelle will not begin field operations without these clearances and permits.

2. The Air Force will be responsible for obtaining Base and site clearance for the Battelle staff that will be working at the Base. The Base POC will be furnished with all necessary information on each staff member at least 1 week prior to field startup.

3. Access to the local sanitary sewer must be furnished so that Battelle staff can discharge the bioslurper aqueous effluent directly to the Base treatment facility.

4. Regulatory approval, if required, must be obtained by the Base POC prior to startup of the bioslurper pilot test. As stated previously, it is likely that a waiver to allow air releases or a point source air release registration will be required for emissions of approximately 65 lb/day of TPH. The TPH and benzene concentration levels are the maximum levels of those components that would be released to the atmosphere. The Base POC will obtain all necessary Base permits prior to mobilization to the site. Battelle will provide technical assistance in preparing regulatory approval documents.

5. The Base also will be responsible for the disposition of all waste generated from the pilot testing. Such waste includes any soil cuttings generated from drilling, and all aqueous wastestreams produced from the bioslurper tests. All free product recovered from the bioslurper operation will be disposed of or recycled by the Base. Battelle will provide technical assistance in disposing of the waste generated from the bioslurper pilot test.

6. Before field activities begin, the Health and Safety Plan will be finalized with information provided by the Base POC. Table 6 is a checklist for the information required to complete the Health and Safety Plan. All emergency information will be obtained by the Site Health and Safety Office before operations begin.

Table 6. Health and Safety Information Checklist

Emergency Contacts	Name	Telephone Number
Hospital Emergency Room:	____________	____________
Point of Contact:	____________	____________
Fire Department:	____________	____________
Emergency Unit (Ambulance):	____________	____________
Security:	____________	____________
Explosives Unit:	____________	____________
Community Emergency Response Coordinator:	____________	____________
Other:	____________	____________
Program Contacts	____________	____________
Air Force:	____________	____________
Battelle:	____________	____________
Other:	____________	____________
Emergency Routes	____________	____________
Hospital (maps attached)		
Other: ____		

6.3 AFCEE Activities

The Air Force Center for Environmental Excellence (AFCEE) POC will act as a liaison between Battelle and Shaw Base staff. The AFCEE POC will ensure that all necessary permits are obtained and the space required to house the bioslurper field equipment is found.

The following is a listing of Battelle, AFCEE, and Shaw Base staff who can be contacted in cases of emergency and/or required technical support during the bioslurper field initiative tests at Shaw AFB.

Battelle POCs	Jeff Kittel	614-424-6122
	Eric Drescher	614-424-3088
AFCEE POC	Patrick Haas	210-536-4314
Shaw AFB POC	____________	____________
Regulator POCs		
Air:	____________	____________
Water:	____________	____________

APPENDIX A

WELL CONSTRUCTION SUMMARY SHEET

Table 2–2. Well Construction Summary
Operable Unit #1, POL Depot
Shaw Air Force Base, South Carolina

22–Jul–93

Well Designation		Previous Designation	Coordinates \A Easting	Coordinates \A Northing	Elevations (ft, msl) Ground Surface	Elevations (ft, msl) Protective Casing \B	Elevations (ft, msl) Well Casing	Depth \C Total \D	Depth \C Screened Interval
MW–634	\3	MW–7	2156008.302	349838.416	246.58	246.66	246.46	52.9	37.6 – 52.6
MW–635	\3	V	2155945.729	351823.946	259.83	259.80	259.28	55.1	40 – 55
MW–636	\3	W	2156156.802	352028.675	259.38	259.49	258.84	54.35	40 – 55
MW–637	\3	X	2156357.121	352014.293	255.70	256.03	255.44	54	39 – 54
MW–638	\3	Y	2156431.696	351870.151	252.61	252.92	252.05	53.45	39 – 54
MW–639	\3	–	2155644.432	349215.727	250.19	250.19	249.93	48.7	33.4 – 48.4
MW–640	\3	–	2155084.241	349275.395	251.51	251.43	251.11	46.6	31.3 – 46.3
MW–641	\3	B–642	2155406.393	349776.899	254.41	254.56	254.56	74.4	59.1 – 74.1
RW–4	\4		2156207.601	351533.016	253.97		252.30	60	34.5 – 59.5
RW–5	\4		2156205.348	351466.093	253.16		251.78	61.5	36 – 61
RW–6	\4		2156328.195	351484.191	252.58		250.93	61	30.5 – 60.5
RW–7	\4		2156287.389	351424.690	252.74		251.29	61	30.2 – 60.2
RW–8	\4		2156374.873	351424.936	251.52		249.93	63	32 – 62
RW–9	\4		2156323.021	351361.703	252.57		251.34	63	32 – 62
RW–10	\4		2156354.400	351252.630	251.77		249.98	66	35 – 65
RW–11	\4		2156433.958	351251.746	250.43		249.17	66	30 – 65
RW–12	\4		2156386.661	351161.866	250.92		249.22	72	31.7–61.7

\A = S.C. State Plane Grid Coordinates Surveyed by CARDAN Sytems Corp. or Palmer and Mallard.
\B = Steel Protective Casing if Present, or Steel Manhole Lip if Flush Surface Completion
\C = Feet Below Land Surface
\D = Base of Well Casing/Screen.

\1 = Wells Installed by LAW Environmental (1986–1990).
\2 = Wells Installed by USACE
\3 = Wells Installed by Geraghty & Miller, Inc. (1991–1993).
\4 = Wells Installed by Research Triangle Institute (1984).

APPENDIX B

LABORATORY ANALYTICAL REPORTS

@ AIR TOXICS LTD.

AN ENVIRONMENTAL ANALYTICAL LABORATORY

WORK ORDER #: 9607191

Work Order Summary

CLIENT:	Ms. Amanda Bush Battelle Memorial Institute 505 King Avenue Columbus, OH 43201-2693	**BILL TO:**	Same
PHONE:	614-424-4996	**INVOICE #**	11061
FAX:	614-424-3667	**P.O. #**	91221
DATE RECEIVED:	7/18/96	**PROJECT #**	Shaw AFB
DATE COMPLETED:	7/26/96	**AMOUNT$:**	$421.61

FRACTION #	NAME	TEST	RECEIPT VAC./PRES.	PRICE
01A	SHW-AE-1	TO-3	2.5 "Hg	$120.00
02A	SHW-AE-2	TO-3	1.0 "Hg	$120.00
03A	SHW-AE-3	TO-3	0 "Hg	$120.00
04A	Lab Blank	TO-3	NA	NC

Misc. Charges	1 Liter Summa Canister Preparation (3) @ $15.00 each.	$45.00
	Shipping (7/3/96)	$16.61

CERTIFIED BY: Isabella C. Crume
for Laboratory Director

DATE: 7/26/96

AIR TOXICS LTD.

SAMPLE NAME: SHW-AE-1

ID#: 9607191-01A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

File Name:	**6071909**		**Date of Collection: 7/13/96**	
Dil. Factor:	**22000**		**Date of Analysis: 7/19/96**	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
Benzene	22	71	1900	6200
Toluene	22	84	1900	7300
Ethyl Benzene	22	97	1200	5300
Total Xylenes	22	97	2400	10000

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as JP-4 Jet Fuel)

File Name:	**6071909**		**Date of Collection: 7/13/96**	
Dil. Factor:	**22000**		**Date of Analysis: 7/19/96**	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
TPH* (C5+ Hydrocarbons)	220	1400	13000	84000
C2 - C4** Hydrocarbons	220	400	480	880

*TPH referenced to JP-4 Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: 1 Liter Summa Canister

AIR TOXICS LTD.

SAMPLE NAME: SHW-AE-2
ID#: 9607191-02A

EPA METHOD TO-3
(Aromatic Volatile Organics in Air)

GC/PID

File Name:	**6071911**		**Date of Collection: 7/14/96**	
Dil. Factor:	**11000**		**Date of Analysis: 7/19/96**	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
Benzene	11	36	700	2300
Toluene	11	42	1100	4200
Ethyl Benzene	11	49	590	2600
Total Xylenes	11	49	1200	5300

TOTAL PETROLEUM HYDROCARBONS
GC/FID
(Quantitated as JP-4 Jet Fuel)

File Name:	**6071911**		**Date of Collection: 7/14/96**	
Dil. Factor:	**11000**		**Date of Analysis: 7/19/96**	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
TPH* (C5+ Hydrocarbons)	110	710	12000	78000
C2 - C4** Hydrocarbons	110	200	960	1800

*TPH referenced to JP-4 Jet Fuel (MW=156)
**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: 1 Liter Summa Canister

AIR TOXICS LTD.

SAMPLE NAME: SHW-AE-3
ID#: 9607191-03A

EPA METHOD TO-3
(Aromatic Volatile Organics in Air)

GC/PID

File Name:	**6071913**		**Date of Collection: 7/16/96**	
Dil. Factor:	**202000**		**Date of Analysis: 7/19/96**	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
Benzene	200	650	11000	36000
Toluene	200	770	14000	54000
Ethyl Benzene	200	880	9800	43000
Total Xylenes	200	880	20000	88000

TOTAL PETROLEUM HYDROCARBONS
GC/FID
(Quantitated as JP-4 Jet Fuel)

File Name:	**6071913**		**Date of Collection: 7/16/96**	
Dil. Factor:	**202000**		**Date of Analysis: 7/19/96**	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
TPH* (C5+ Hydrocarbons)	2000	13000	130000	840000
C2 - C4** Hydrocarbons	2000	3700	9300	17000

*TPH referenced to JP-4 Jet Fuel (MW=156)
**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: 1 Liter Summa Canister

AIR TOXICS LTD.

SAMPLE NAME: Lab Blank

ID#: 9607191-04A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

File Name:	6071906		Date of Collection: NA	
Dil. Factor:	1.00		Date of Analysis: 7/19/96	
Compound	Det. Limit (ppmv)	Det. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
Benzene	0.001	0.003	Not Detected	Not Detected
Toluene	0.001	0.004	Not Detected	Not Detected
Ethyl Benzene	0.001	0.004	Not Detected	Not Detected
Total Xylenes	0.001	0.004	Not Detected	Not Detected

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as JP-4 Jet Fuel)

File Name:	6071906		Date of Collection: NA	
Dil. Factor:	1.00		Date of Analysis: 7/19/96	
Compound	Det. Limit (ppmv)	Det. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
TPH* (C5+ Hydrocarbons)	0.010	0.065	Not Detected	Not Detected
C2 - C4** Hydrocarbons	0.010	0.018	Not Detected	Not Detected

*TPH referenced to JP-4 Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: NA

AIR TOXICS LTD.
AN ENVIRONMENTAL ANALYTICAL LABORATORY

180 BLUE RAVINE ROAD, SUITE B
FOLSOM, CA 95630-4719
(916) 985-1000 FAX: (916) 985-1020

CHAIN-OF-CUSTODY RECORD

№ 007724

Page 1 of 1

Contact Person MATT PLACE
Company BATTELLE
Address 505 King Ave City Columbus State OH Zip 43201
Phone 614-424-4531 FAX 614-424-3667
Collected By: Signature [signature]

Project info:
P.O. # 91221
Project # SHAW AFB
Project Name

Turn Around Time:
☒ Normal
☐ Rush ______ Specify

Lab I.D.	Field Sample I.D.	Date & Time	Analyses Requested	Canister Pressure / Vacuum Initial	Final	Receipt
01A	SHW-AE-1	13 July 96 1605	BTEX, TPH AS JP-4	26"Hg	0"Hg	2.5"Hg
02A	SHW-AE-2	14 July 96 1812	BTEX, TPH AS JP-4	25"Hg	0"Hg	1.0"Hg
03A	SHW-AE-3	15 July 96	BTEX, TPH AS JP-4	26"Hg	0"Hg	0"Hg
						7/18/96

Relinquished By: (Signature) [signature] Date/Time 16 July 96 1104 Print Name MARTIN WHEELER

Relinquished By: (Signature) Date/Time Received By: (Signature) Date/Time

Relinquished By: (Signature) Date/Time Received By: (Signature) [signature] ATL Date/Time 7/18/96 10:55

Notes:

Lab Use Only	Shipper Name	Air Bill #	Opened By:	Date/Time	Temp. (°C)	Condition	Custody Seals Intact?	Work Order #
	Fed Ex	0769857896	[signature]	7/18/96 1055	Ambient	Good	Yes No None N/A	9607191

Form 1293 rev. 06

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
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FAX: 702-355-0406
1-800-283-1183

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http//www.powernet.net/~alpha

2505 Chandler Avenue, Suite 1
Las Vegas, Nevada 89120
(702) 498-3312
FAX: 702-736-7523
1-800-283-1183

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: Shaw AFB Pilot Test
Phone: (614) 424-6199
Attn:

Sampled: 07/13-15/96 Received: 07/18/96 Analyzed: 07/24/96

Matrix: [ ] Soil [X] Water [ ] Waste

Analysis Requested: TPH - Total Petroleum Hydrocarbons-Purgeable Quantitated As Gasoline

Methodology: TPH - Modified 8015/DHS LUFT Manual/BLS-191

Results:

Client ID/ Lab ID	Parameter	Concentration mg/L	Detection Limit mg/L
SHWDC 2 /BMI071896-05	TPH (Purgeable)	3.0	0.50
SHWDC 4 /BMI071896-07	TPH (Purgeable)	2.9	0.50
SHWDC 6 /BMI071896-09	TPH (Purgeable)	2.3	0.50

ND - Not Detected

Approved by: Roger L. Scholl Date: 8/1/96
Roger L. Scholl, Ph.D.
Laboratory Director

Alpha Analytical, Inc.
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Sparks, Nevada 89431
(702) 355-1044
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Las Vegas, Nevada 89120
(702) 498-3312
FAX: 702-736-7523
1-800-283-1183

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: Shaw AFB Pilot Test
Phone: (614) 424-6199
Attn:

Sampled: 07/13-15/96 Received: 07/18/96 Analyzed: 07/23/96

Matrix: [ ] Soil [X] Water [ ] Waste

Analysis Requested: BTEX - Benzene, Toluene, Ethylbenzene, Xylenes

Methodology: BTEX - EPA Method 624/8240

Results:

Client ID/ Lab ID	Parameter	Concentration ug/L	Detection Limit ug/L
SHWDC 1 /BMI071896-04	Benzene	62	50
	Toluene	310	50
	Ethylbenzene	110	50
	Total Xylenes	640	50
SHWDC 3 /BMI071896-06	Benzene.	76	50
	Toluene	300	50
	Ethylbenzene	97	50
	Total Xylenes	610	50
SHWDC 5 /BMI071896-08	Benzene	110	50
	Toluene	320	50
	Ethylbenzene	100	50
	Total Xylenes	630	50

ND - Not Detected

Convert Conc

Approved by: Roger L. Scholl
Roger L. Scholl, Ph.D.
Laboratory Director

/ /96

Laboratory Analysis Report

Sierra Environmental Monitoring, Inc.

ALPHA ANALYTICAL
255 GLENDALE AVENUE, SUITE 21
SPARKS NV 89431

Date : 8/02/96
Client : ALP-855
Taken by: CLIENT
Report : 16922
PO# :

Page: 1

Sample	Collected Date	Collected Time	MOISTURE CONTENT %	DENSITY G/CM3	POROSITY %	PARTICLE SIZE DISTIBUTION FRACTION %		
BMI071896-02 - SHW-S-1	7/10/96	12:03	1.8	1.52	42.7	See Report		
BMI071896-03 - SHW-S-2	7/10/96	13:10	2.3	1.42	46.4	See Report		

pproved By: ______________________

This report is applicable only to the sample received by the laboratory. The liability of the laboratory is limited to the amount paid for this report. This report is for the exclusive use of the client to whom it is addressed and upon the condition that the client ssumes all liability for the further distribution of the report or its contents.

Villiam F. Pillsbury
President

1135 Financial Blvd.
Reno, NV 89502
Phone (702) 857-2400
FAX (702) 857-2404

John C. Seher
Manager

Sierra
Environmental
Monitoring, Inc.

August 2, 1996

TO: **Alpha Analytical**

FROM: Sierra Environmental Monitoring, Inc.

RE: Particle Size Distribution Analysis for Samples:

SEM 9607-0804	BMI 071896-02-SHW-S1
SEM 9607-0805	BMI 071896-03-SHW-S1

As per your request, we have performed particle size analysis on the samples submitted to our laboratory. Test results are as follows:

9607-0804	**Clay: 0.0 %**	**Silt: 1.9 %**	**Sand: 98.1 %**
9607-0805	**Clay: 0.0 %**	**Silt: 1.9 %**	**Sand: 98.1 %**

The samples were passed through a #10 sieve prior to analysis as per procedure. All results are based on oven dry sample weights.

We appreciate this opportunity to provide our laboratory testing services. If you have any questions or require further testing, please feel free to contact us at your convenience.

Sincerely,
SIERRA ENVIRONMENTAL MONITORING, INC.

John Seher
Laboratory Manager

William F. Pillsbury
President

1135 Financial Blvd.
Reno, NV 89502
Phone (702) 857-2400
FAX (702) 857-2404

John C. Seher
Manager

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
(702) 355-1044
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1-800-283-1183

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: 91222
Phone: (614) 424-6199
Attn: Martin Wheeler

Sampled: 07/10/96 Received: 07/18/96 Analyzed: 07/23/96

Matrix: [X] Soil [ ] Water [ ] Waste

Analysis Requested: TPH - Total Petroleum Hydrocarbons-Purgeable Quantitated As Gasoline
BTEX - Benzene, Toluene, Ethylbenzene, Xylenes

Methodology: TPH - Modified 8015/DHS LUFT Manual/BLS-191
BTEX - Method 624/8240

Results:

Client ID/ Lab ID	Parameter	Concentration	Detection Limit	
SHW-S-1 /BMI071896-02	TPH (Purgeable)	390	50	mg/Kg
	Benzene	ND	100	ug/Kg
	Toluene	130	100	ug/Kg
	Ethylbenzene	280	100	ug/Kg
	Total Xylenes	1,800	100	ug/Kg
SHW-S-2 /BMI071896-03	TPH (Purgeable)	380	50	mg/Kg
	Benzene	ND	100	ug/Kg
	Toluene	160	100	ug/Kg
	Ethylbenzene	330	100	ug/Kg
	Total Xylenes	2,500	100	ug/Kg

ND - Not Detected

Approved by: Roger L. Scholl Date: 7/24/96
Roger L. Scholl, Ph.D.
Laboratory Director

[redacted]ng In[redacted]atio[redacted]

Name

Address

City, State, Zip

Phone Number ____ Fax ____

[redacted]pha A[redacted]ytical, [redacted]nc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
Phone (702) 355-1044
Fax (702) 355-0406

Page # 1 of 1

Client Name: Battelle	P.O. #: 91272	Job #:	
Address:	PWS #:	DWR #:	
City, State, Zip:	Phone #: 4057325564	Fax #:	

Sampled by: Martin Wheeler

Report Attention:

Analyses Required

Time Sampled	Date Sampled	Matrix* See Key Below	Office Use Only Lab ID Number	Sample Description	Total and type of containers ** See below	Sieve Grain Size Analyses	BTXE	TPH (IR4)	Bulk Density	Porosity	Moisture Content						
1203	7/10	SO	BMI071896-02	SHW-S-1	1B	+	+	+	+	+	+						
1310	✓	✓	-03	SHW-S-2	1B	+	+	+	+	+	+						

REMARKS:

Spoke w/ Martin Wheeler 7/22/96, he will call back + let us know what to do w/these.

	Signature	Print Name	Company	Date	Time
Relinquished by					
Received by	Katherine Z Souza	KZ Souza	AAI	7-18-96	1000
Relinquished by	[signature]	Craig Giesy	AAI	7/22/96	1150
Received by	[signature]	[signature]	SCM	7-22-96	1150
Relinquished by					
Received by					

NOTE: Samples are discarded 60 days after results are reported unless other arrangements are made. Hazardous samples will be returned to client or disposed of at client expense.

*Key: AQ - Aqueous SO - Soil WA - Waste OT - Other **: L-Liter V-Voa S-Soil Jar O-Orbo T-Tedlar B-Brass P-Plastic OT-Other

Battelle
Columbus Laboratories

CHAIN OF CUSTODY RECORD

Form No. ______

Proj. No.	Project Title
G462201-30B1801	SHAW AFB Pilot Study

SAMPLERS: (Signature) Shane S. Walton

SAMPLE TYPE (√)

DATE	TIME	SAMPLE I.D.	Particle-size dist.	Bulk density	Porosity	Moisture Content	BTEX	TPH as JP-4	Container No.	Number of Containers	Remarks
7-10-96	1115 hrs	SHW-S-1	X	X	X	X	X	X		1	
7-10-96	1115 hrs	SHW-S-2	X	X	X	X	X	X		1	

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)
Shane S. Walton	07/17/96 7:30am				

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)

Relinquished by: (Signature)	Date/Time	Received for Laboratory by: (Signature)	Date/Time	Remarks

Page ____ of ____

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FAX: 702-736-7523
1-800-283-1183

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: Shaw AFB: Pilot Study
Phone: (614) 424-6199
Attn:

Sampled: 07/16/96 Received: 07/18/96 Analyzed: 07/24/96

Matrix: [X] Soil [ ] Water [ ] Waste

Analysis Requested: BTEX - Benzene, Toluene, Ethylbenzene, Xylenes

Methodology: BTEX - EPA Method 624/8240

Results:

Client ID/ Lab ID	Parameter	Concentration mg/Kg	Detection Limit mg/Kg
SHW-FP-1 /BMI071896-01	Benzene	1300	1100
	Toluene	7100	1100
	Ethylbenzene	3300	1100
	Total Xylenes	17000	1100

ND - Not Detected

Approved by: Roger L. Scholl Date: 7/31/96
Roger L. Scholl, Ph.D.
Laboratory Director

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
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http//www.powernet.net/~alpha

2505 Chandler Avenue, Suite 1
Las Vegas, Nevada 89120
(702) 498-3312
FAX: 702-736-7523
1-800-283-1183

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: G462201-30B1801
Phone: (614) 424-6199
Attn: Eric Foote

Alpha Analytical Number: BMI071896-01

Client I.D. Number: SHW-FP-1

Date Sampled: 07/16/96

Date Received: 07/18/96

C-range Compounds	Method	Percentage of Total	Detection Limit (Not Applicable)	Date Analyzed
C09<	GC/FID	49.93	NA	07/31/96
C10	GC/FID	13.04	NA	07/31/96
C11	GC/FID	11.19	NA	07/31/96
C12	GC/FID	10.35	NA	07/31/96
C13	GC/FID	7.98	NA	07/31/96
C14	GC/FID	4.69	NA	07/31/96
C15	GC/FID	1.92	NA	07/31/96
C16	GC/FID	0.54	NA	07/31/96
>C17	GC/FID	0.36	NA	07/31/96

Approved by: Roger L. Scholl

Roger L. Scholl, Ph.D.
Laboratory Director

Date: 8/1/96

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
(702) 355-1044
FAX: 702-355-0406
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e-mail: alpha@powernet.net
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2605 Chandler Avenue, Suite 1
Las Vegas, Nevada 89120
(702) 498-3312
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1-800-283-1183

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: G462201-30B1801
Phone: (614) 424-6199
Attn: Eric Foote

Alpha Analytical Number: BMI071896-01

Client I.D. Number: SHW-FP-1

Date Sampled: 07/16/96

Date Received: 07/18/96

C-range Compounds	Method	Percentage of Total	Detection Limit (Not Applicable)	Date Analyzed
C09<	GC/FID	49.93	NA	07/31/96
C10	GC/FID	13.04	NA	07/31/96
C11	GC/FID	11.19	NA	07/31/96
C12	GC/FID	10.35	NA	07/31/96
C13	GC/FID	7.98	NA	07/31/96
C14	GC/FID	4.69	NA	07/31/96
C15	GC/FID	1.92	NA	07/31/96
C16	GC/FID	0.54	NA	07/31/96
>C17	GC/FID	0.36	NA	07/31/96

Approved by: Roger L. Scholl

Roger L. Scholl, Ph.D.
Laboratory Director

Date: 8/1/96

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Las Vegas, Nevada 89120
(702) 498-3312
FAX: 702-736-7523
1-800-283-1183

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: Shaw AFB: Pilot Study
Phone: (614) 424-6199
Attn:

Sampled: 07/16/96 Received: 07/18/96 Analyzed: 07/24/96

Matrix: [X] Soil [ ] Water [ ] Waste

Analysis Requested: BTEX - Benzene, Toluene, Ethylbenzene, Xylenes

Methodology: BTEX - EPA Method 624/8240

Results:

Client ID/ Lab ID	Parameter	Concentration mg/Kg	Detection Limit mg/Kg
SHW-FP-1	Benzene	1300	1100
/BMI071896-01	Toluene	7100	1100
	Ethylbenzene	3300	1100
	Total Xylenes	17000	1100

ND - Not Detected

Approved by: Roger L. Scholl Date: 7/31/96
Roger L. Scholl, Ph.D.
Laboratory Director

APPENDIX C

SYSTEM CHECKLIST

Checklist for System Shakedown

Site: SS-15, Shaw AFB

Date: 8 July '96

Operator's Initials: _____

Equipment	Check if OK	Comments
Liquid Ring Pump	✓	
Aqueous Effluent Transfer Pump	✓	
Oil/Water Separator	✓	
Vapor Flow Meter	✓	
Fuel Flow Meter	✓	
Water Flow Meter	✓	
Emergency Shut Off float Switch Effluent Transfer Tank	✓	
Analytical Field Instrumentation GasTechtor O_2/CO_2 Analyzer TraceTechtor Hydrocarbon Analyzer Oil/Water Interface Probe Magnehelic Boards Thermocouple Thermometer	 ✓ ✓ ✓ ✓ ✓	

APPENDIX D

DATA SHEETS FROM THE SHORT-TERM PILOT TEST

ATMOSPHERIC OBSERVATIONS

Site: Shaw AFB

Operators: S. Walton

Date/Time	Ambient Temperature °F	~~Relative Humidity~~	~~Barometric Pressure~~
7.12.96 / 8:31	74.6		
/ 17:30	79.0		
7.13.96 / 8:00	78.0		
16:00	101.6		
17:30	92.4		
7.14.96 / 8:30	82.2		
17:30	92.8		
7.15.96 / 8:30	80.2		
15:30	91.0		
7.16.96 / 8:40	81.2		
15:00	91.2		
7.17.96 / 8:10	84.4		
17:45	90.2		
7.18.96 / 8:30	81.0		
12:00	95.6		

Baildown Test Record Sheet

Site: Shaw AFB

Well Identification: MW

Well Diameter (OD/ID): ______

Date at Start of Test: 7-8-96

Sampler's Initials: ____

Time at Start of Test: 13:30

Initial Readings

Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)	Total Volume Bailed (L)
		6.51	

Test Data

Sample Collection Time	Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)
13:58	51.36	50.71	.65
14:00	51.15	50.29	.86
14:02	50.89	49.81	1.08
14:06	50.28	49.21	1.07
14:09	50.01	48.99	1.02
14:11	49.82	48.89	.93
14:14	49.45	48.63	.82
14:18	49.29	48.44	.85
14:22	49.16	48.21	.95
14:26	49.02	48.01	1.01
14:31	48.88	47.79	1.09
14:36	48.81	47.59	1.22

Figure 9. Typical Baildown Test Record Sheet

Page 2

Baildown Test Record Sheet

Site: Shaw AFB

Well Identification: MW

Well Diameter (OD/ID):

Date at Start of Test: 7-8-96

Sampler's Initials:

Time at Start of Test: 13:30

Initial Readings

Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)	Total Volume Bailed (L)

Test Data

Sample Collection Time	Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)
14:41	48.77	47.31	1.46
15:14	48.75	46.61	1.99
15:49	48.81	46.41	2.40
18:22	49.46	45.85	3.61

Figure 9. Typical Baildown Test Record Sheet

Baildown Test Record Sheet

Site: Shaw AFB

Well Identification: MW644

Well Diameter (OD/ID): ______

Date at Start of Test: 7/08/96

Sampler's Initials: ______

Time at Start of Test: 14:52

Initial Readings

Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)	Total Volume Bailed (L)
		4.34	

Test Data

Sample Collection Time	Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)
14:52	47.62	45.89	1.73
14:54	47.55	45.81	1.74
14:55	47.52	45.75	1.77
14:56	47.42	45.65	1.77
14:59	47.34	45.57	1.77
15:02	47.25	45.43	1.82
15:13	47.00	45.07	1.93
15:18	46.95	44.96	1.99
15:29	46.83	44.78	2.05
16:01	46.81	44.76	2.35
18:11	47.24	44.09	3.15

Figure 9. Typical Baildown Test Record Sheet

Page ____ of ____

Pilot Test Monitoring Well Data Sheet

Site: Shaw AFB

Test Type (Skimmer, Bioslurper Vacuum Extraction, Draw Down): Bioslurper

Depth to Groundwater: ________ Depth to Fuel: ________ Depth of Slurper Tube: ________

Date at Start of Test: 7·11·96

Time at Start of Test: 12:00

Operators Initials: ________

	Time	Well ID: 643			Well ID:			Well ID:			Well ID:		
		LNAPL Level (ft)	Water Level (ft)	LNAPL Thickness ~~Pressure (in H_2O)~~	LNAPL Level	Water Level	Pressure (in H_2O)	LNAPL Level	Water Level	Pressure (in H_2O)	LNAPL Level	Water Level	Pressure (in H_2O)
	T=0												
7·12·96	8:31	44.04	48.23	4.19									
	17:30	44.05	48.23	4.18									
7·13·96	8:00	44.09	48.23	4.14									
	16:00	44.10	48.23	4.13									
	17:30	44.10	48.23	4.13									
7·14·96	8:30	44.14	48.225	4.085									
	17:30	44.15	48.23	4.08									
7·15·96	8:30	44.19	48.22	4.03									
	15:30	44.19	48.22	4.03									

Figure 14. Typical Record Sheets for Bioslurper Pilot Testing

Bioslurping Pilot Test
(Data Sheet 2)
Pilot Test Pumping Data

Page ____ of ____

Site: Shaw AFB

Operators: S. Waltson

Test Type: Initial Skimmer

Depth to Groundwater: ________ Depth to Fuel: ________

Start Date: 7-9-96

Start Time: 11:48

Well ID: MW644

Depth of Tube: ________

Date/Time	Run Time	Vapor Extraction: Stack Pressure (In. H_2O)	~~Carbon Drums (In. H_2O)~~	Flowrate (scfm)	Seal Tank ~~Pump Stack~~ Temp °F	Pump Head Vacuum (in. Hg)	Extraction Well Vacuum (in. H_2O)
7-9-96/14:30	2.7	.09				16.0	
17:44	5.9	.01				18.5	
7-10-96/7:55	20.1	.005			129.0	17.0	
20:05	32.3	ND			127.0	16.0	
7-11-96/11:04	47.3	.015			122.2	16.5	
11:30	23.7	shutdown					

Figure 11. Typical Record Sheets for Bioslurper Pilot Testing (Continued)

Biosturping Pilot Test
(Data Sheet 2)
Pilot Test Pumping Data

Page ____ of ____

Site: Shaw AFB

Operators: S Walton

Test Type: Bioslurper

Depth to Groundwater: ________ Depth to Fuel: ________

Start Date: 7.11.96

Start Time: 12:00

Well ID: MW 644

Depth of Tube: ________

Date/Time	Run Time	Vapor Extraction: Stack Pressure (in. H_2O)	Vapor Extraction: ~~Carbon Drums (in. H_2O)~~	Vapor Extraction: Flowrate (scfm)	Seal Tank ~~Pump Stack~~ Temp °F	Pump Head Vacuum (in. Hg)	Extraction Well Vacuum (in. H_2O)
7.11.96 13:06	1.1	.01			117.6	19.0	26
		ND			122.4		24
16:45	4.7						12
17:00	5.0	.025				16.0	12
7.12.96 8:31	20.5	.01			121.4	19.0	13.5
17:30	29.5	.01			128.6	19.0	13
7.13.96 8:00	44.0	.02			130.8	19.0	13.5
1600	52.0	.01			139.4	18.5	13
17:30	53.5	.055			128.0	18.0	22
7.14.96 8:30	68.5	.02			125.0	18.0	22
17:30	77.5				129.0	17.5	22
7.15.96 8:30	92.5	.07			122.8	18.0	22
1530	99.5	.04			128.8	18.0	21

Figure 11. Typical Record Sheets for Bioslurper Pilot Testing (Continued)

Bioslurping Pilot Test
(Data Sheet 2)
Pilot Test Pumping Data

Page ____ of ____

Site: Shaw AFB

Operators: S. Walton

Test Type: Second Skimmer

Depth to Groundwater: N/A Depth to Fuel: N/A

Start Date: 7.15.96

Start Time: 1616

Well ID: MW644

Depth of Tube: ________

		Vapor Extraction					
Date/Time	Run Time	Stack Pressure (in. H_2O)	~~Carbon Drums (in. H_2O)~~	Flowrate (scfm)	Seal Tank ~~Pump Stack~~ Temp ~~[illegible]~~ °F	Pump Head Vacuum (in. Hg)	Extraction Well Vacuum (in. H_2O)
7.16.96 8:40	16.4	.11			124.8	15.5	N/A
1500	22.7	.12			128.0	15.0	N/A

Figure 11. Typical Record Sheets for Bioslurper Pilot Testing (Continued)

Bioslurping Pilot Test
(Data Sheet 2)
Pilot Test Pumping Data

Page ____ of ____

Site: Shaw AFB

Operators: S. Walton

Test Type: Drawdown

Depth to Groundwater: ________ Depth to Fuel: ________

Start Date: 7.16.96

Start Time: 16:00

Well ID: MW644

Depth of Tube: ________

Date/Time	Run Time	Vapor Extraction: Stack Pressure (in. H_2O)	Vapor Extraction: ~~Carbon Drums (in. H_2O)~~	Vapor Extraction: Flowrate (scfm)	Seal Tank ~~Pump Stack~~ Temp ~~(°C)~~ °F	Pump Head Vacuum (in. Hg)	Extraction Well Vacuum (in. H_2O)
7.17.96 8:10	16.2	.075			126.2	17.0	N/A
17:45	25.8	.08			129.6	17.0	
7.18.96 8:30	40.5	7.5			126.6	17.25	
12:00	44.0	.07			132.4	17.0	

Figure 11. Typical Record Sheets for Bioslurper Pilot Testing (Continued)

Bioslurping Pilot Test
(Data Sheet 3B)
Fuel and Water Recovery Data

Page ____ of ____

Site: Shaw AFB

Test Type: Initial Skimmer

Start Date: 7/9/96

Operators: S. Walton

Date/Time	Run Time	LNAPL Recovery (volume collected in time period)	Groundwater Recovery (volume collected in time period)
7/9/96 11:48	0		
14:30	2.7	5 gallons	25 gallons
17:44	5.9	5.3	25
7/10/96 7:55	20.1	9.4	100
20:05	32.3	7.9	150
7/11/96 11:04	47.3	8.5	40
11:30	.7	Shutdown	

Bioslurping Pilot Test
(Data Sheet 3B)
Fuel and Water Recovery Data

Page ____ of ____

Site: Shaw AFB

Test Type: Bioslurper

Start Date: 7/11/96

Operators: S. Walton

Date/Time	Run Time	LNAPL Recovery (volume collected in time period)	Groundwater Recovery (volume collected in time period)
7/11/96 12:00	0	0	
—		14 gallons	90 gallons
7/12/96 8:31	20.5	25.4	180
17:30	29.5	9.3	65
7/13/96 8:00	44.0	18.0	175
16:00	52.0	11.3	150
17:30	53.5	.5	20
7/14/96 8:30	68.5	24.0	175
17:30	77.5	13.5	95
23:00	83.5	System shutdown (1800-2000)	
7/15/96 8:30	92.5	22.0	190
15:30	99.5	12.3	100
16:16	100.3	went to Skimmer test	

Bioslurping Pilot Test
(Data Sheet 3B)
Fuel and Water Recovery Data

Page ____ of ____

Site: Shaw AFB   Test Type: Second Skimmer

Start Date: 7/15/96   Operators: S. Walton

Date/Time	Run Time	LNAPL Recovery (volume collected in time period)	Groundwater Recovery (volume collected in time period)
7/15/96 16:16			
7/16/96 8:40	16.4	16.6 gallons	130 gallons
15:00	22.7	4.6	50

Bioslurping Pilot Test
(Data Sheet 3B)
Fuel and Water Recovery Data

Page ___ of ___

Site: Shaw AFB   Test Type: Drawdown

Start Date: 7/16/96   Operators: S. Walton

Date/Time	Run Time	LNAPL Recovery (volume collected in time period)	Groundwater Recovery (volume collected in time period)
7/16/96 16:00			
7/17/96 8:10	16.2	21.0 gallons	175 gallons
17:45	25.8	12.3	85
7/18/96 8:30	40.5	15.7	140
12:00	44.0	5.2	35

APPENDIX E

SOIL GAS PERMEABILITY TEST RESULTS

BATTELLE	RECORD SHEET FOR AIR PERMEABILITY TEST				DATE/TIME: 7/11/96 12:00
DISTANCE FROM VENT WELL (ft. & tenths)	10.0	10.0	10.0		SITE: ~~MPA~~ Shaw AFB
TIME FROM START-UP (MIN.)	PT. CODE	PT. CODE	PT. CODE	PT. CODE	RECORDED BY: S. Walton
	MPA—GREEN	MPA—BLUE	MPA—RED		COMMENTS
	PRESSURE (IN H_2O)	PRESSURE (IN H_2O)	PRESSURE (IN H_2O)	PRESSURE (IN H_2O)	
2	.20	.22	.235		
5	.215	.25	.25		
10	.25	.25	.25		
20	.25	.25	.25		
45	.25	.25	.25		
75	.50	.50	.50		
240	.55	.55	.55		

BATTELLE	RECORD SHEET FOR AIR PERMEABILITY TEST				DATE/TIME: 7/11/96 / 12:00
DISTANCE FROM VENT WELL (ft. & tenths)	20.0	20.0	20.0		SITE: ~~MPB~~ Shaw AFB
TIME FROM START-UP (MIN.)	PT. CODE	PT. CODE	PT. CODE	PT. CODE	RECORDED BY: S. Walton
	MPB-GREEN	MPB-Blue	MPB-Red		COMMENTS
	PRESSURE (IN H_2O)	PRESSURE (IN H_2O)	PRESSURE (IN H_2O)	PRESSURE (IN H_2O)	
1	.55	.95	.1		
5	.1	.15	.15		
10	.12	.15	.15		
15	.12	.14	.16		
20	.12	.14	.16		
45	.13	.15	.17		
75	.17	.185	.19		
240	.155	.17	.19		

BATTELLE	RECORD SHEET FOR AIR PERMEABILITY TEST				DATE/TIME: 7/11/96 / 12:00
DISTANCE FROM VENT WELL (ft. & tenths)	30.0	30.0	30.0		SITE: ~~MPC~~ Shaw AFB
TIME FROM START-UP (MIN.)	PT. CODE	PT. CODE	PT. CODE	PT. CODE	RECORDED BY: S. Walton
	MPC-Blue	MPC-Green	MPC-Red		COMMENTS
	PRESSURE (IN H_2O)	PRESSURE (IN H_2O)	PRESSURE (IN H_2O)	PRESSURE (IN H_2O)	
0	0	0	0		
1	.03	.03	.03		
5	.10	.10	.105		
10	.11	.115	.11		
15	.11	.12	.12		
20	.12	.12	.12		
45	.135	.145	.15		
75	.18	.18	.185		
240	.20	.19	.185		

APPENDIX F

IN SITU RESPIRATION TEST RESULTS

Record Sheet for In Situ Respiration Test

Site Shaw AFB	Monitoring Point MPA- Green
Shutdown Date 7-18-96	O_2/CO_2 Meter No. / TPH Meter No.
Shutdown Time 9:00	Recorded by S. Walton

Date	Time	O_2 (%)	CO_2 (%)	TPH (ppm)	He (%)	Temperature (°C)	Comments
7-18-96	905	17.5	0	0	3.1		
	916	19.0	0	0	2.8		
	933	19.5	0	0	2.7		
	1002	19.75	0	0	1.1		
	1038	19.0	0	0	2.2		
	1113	16.5	0	0	1.5		
	1215	10.25	0	3600	.65		
	1318	10.0	0	3600	.57		

Record Sheet for In Situ Respiration Test

Site Shaw AFB	Monitoring Point MPA-Blue
Shutdown Date 7-18-96	O_2/CO_2 Meter No. / TPH Meter No.
Shutdown Time 9:00	Recorded by S. Walton

Date	Time	O_2 (%)	CO_2 (%)	TPH (ppm)	He (%)	Temperature (°C)	Comments
7-18-96	904	18.75	0	0	3.1		
	915	18.50	0	0	1.2		
	932	19.5	0	0	2.1		
	1001	19.0	0	0	1.9		
	1036	10.0	1.0	400	1.3		
	1109	7.0	0	1,200	.86		
	1213	3.5	2.5	3,600	.54		
	1318	2.0	3.75	4,000	.05		

Record Sheet for In Situ Respiration Test

Site Shaw AFB

Shutdown Date 7-18-96

Shutdown Time 9:00

Monitoring Point A - Red

O_2/CO_2 Meter No.

TPH Meter No.

Recorded by S. Walton

Date	Time	O_2 (%)	CO_2 (%)	TPH (ppm)	He (%)	Temperature (°C)	Comments
7-18	903	19.0	0	0	12.0		
	912	20.0	0	0	3.1		
	931	15.5	0	0	.16		
	1000	0.0	5.5	10,800	.17		
	1034	0.0	6.0	16,000	.01		
	1107	0.0	5.0	19,200	.3		
	1211	0.0	4.5	720,000	0		

INSITU.RS (G462201-1001 DISK

Record Sheet for In Situ Respiration Test

Site Shaw AFB	Monitoring Point D- Green
Shutdown Date 7-18-96	O_2/CO_2 Meter No. / TPH Meter No.
Shutdown Time 9:00	Recorded by S. Walton

Date	Time	O_2 (%)	CO_2 (%)	TPH (ppm)	He (%)	Temperature (°C)	Comments
7-18-96	900	20.25	0	0	1.9		
		20.0	0	0	1.6		
	930	20.0	0	0	1.7		
	1004	20.0	0	0	1.4		
	1032	20.0	0	0	1.5		
	1114	20.0	0	0	1.4		
	1209	20.0	0	0	1.4		
	1318	20.0	0	1200	1.2		